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Major P. A. MACMAHON, D.Sc., Sc.D., LL.D., F.R.S., PRESIDENT, in the Chair.

John Beebe, "La Rocca," East Bendigo, Victoria, Australia;
George Rusby Kaye, Curator of the Bureau of Education of the Government of India, Simla, India; and
John Stewart, 45 Raleigh Street, Essendon, Melbourne, Australia,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Arthur Brinley Mayne, B.A. (Oxon.), Mathematical Master at Trinity College, Glenalmond, Perthshire, and 3 Bryn-y-mor Crescent, Swansea (proposed by H. H. Turner);
Wilfred C. Parkinson, Observer, Department of Terrestrial Magnetism of the Carnegie Institution of Washington, The Observatory, Perth, Western Australia (proposed by A. D. Ross); and
Thomas James Richmond, B.Sc. (Lond.), Cartographer, Hydrographic Department, Admiralty, "Eastdene," St. James' Road, Sutton, Surrey (proposed by David J. R. Edney).

Sixty-two presents were announced as having been received since the last ordinary Meeting, including, amongst others:—

Tacubaya, Observatorio Astronomico, Catalogo Astrofotographico, -9° a -17°, tomo 1 (presented by the Observatory).

Photographs of Jupiter, taken Oct.–Dec. 1916 (presented by J. H. Reynolds).

The Star Identifier, and diagram for the graphical solution of problems in nautical Astronomy (Planisphere, with explanation and examples). Constructed and presented by J. E. McGegan.

On Frederick de Houtman's Catalogue of Southern Stars, and the Origin of the Southern Constellations. By E. B. Knobel.

The origin of the constellations surrounding the South Pole is involved in much obscurity. They have all been attributed to various Dutch, Spanish, Portuguese, and Italian navigators, but the original records of the observation and formation of the different constellations appear to be lost.

The earliest existing map of the southern heavens is found in the map of the world made by Peter Plancius in 1594, entitled "Orbis terrarum typus de integro multis in locis emendatus Petro Plancio, 1594," given by Linschoten (*Navigatio ac Itinerarium*, 1599). In this map, besides the Ptolemy constellations, are shown Columba (the stars of which are in Ptolemy), Crux as a separate constellation (also in Ptolemy), Eridanus continued from Ptolemy's 34th star to α Eridani, Triangulum Australe, and a large constellation in the figure of a man called Polophilax, consisting of seven stars which I have not identified. The two Nubeculæ are shown, but nothing else. It is tolerably clear that at this date no other southern constellations were known. Thomas Hood (*Celestial Map*, 1590) states that no more stars than those in Ptolemy have been observed.

The earliest publications containing the constellations surrounding the South Pole as we know them, are in Frederick de Houtman's *Catalogue of Stars*, Bayer's *Uranometria*, and Blaeu's *Celestial Globe*, which all appeared in the same year, 1603.

In the 49th map of Bayer's *Uranometria*, published at Augsburg, 1603 September, are shown the constellations Phœnix, Hydrus, Tucana, Grus, Indus, Pavo, Apus, Triangulum Australe, Musca, Chamæleon, Volans, and Doradus. His map of Eridanus shows the continuation beyond the last of Ptolemy's stars to α Eridani; it also gives some stars in Phœnix and Doradus; that of Canis Major gives Columba, "recentioribus Columba"; Argo shows some stars in Volans; Centaurus includes Crux as a figure, and Triangulum Australe; Ara shows some stars in Triangulum, Grus, and Pavo; Piscis Austrinus includes stars in Grus. Bayer states that these constellations were observed partly by Amerigo Vespucci, partly by Andrea Corsali and Pedro de Medina, but their places were determined by that "most learned" seaman Petrus Theodorus.

Blaeu in his *Celestial Globe*, published in 1603, ascribes all the above constellations to Frederick de Houtman. Merula (*Cosmo-*

graphia Generalis, 1605) attributes all the observations of the "longitudes, latitudes, declinations, etc.," of the stars in question to Petrus Theodorus. Julius Schiller (1627) quotes Bayer, and mentions that these constellations are found on globes by "Petrus Plancius, seu Petrus Karif, Jansonius (Blaeu), and Houtman, etc." Sherburne (1675) says that these constellations were "first found out and denominated by some eminent navigators sayling beyond the line, as particularly by Americus Vespuccius, Andreas Corsalius, Petrus Medina, but principally by Fredericus Houthman, who, during his abode in the island of Sumatra, made exact observations of them, being by Petrus Theodorus and Jacobus Bartschius reduced into order." Weidler gives merely the statements of Bayer and Blaeu. Ideler gives equal merit to Petrus Theodorus and Frederick de Houtman.

I have explored the resources of the British Museum as far as possible, to throw light upon the claims of the above persons.

Of Amerigo Vespucci it is quite clear that he contributed little or nothing to our knowledge of the southern heavens. He states that "the stars of the South Pole are much larger and brighter than those of our pole"; though, in a work published two years before his death (*Sensuyt le nouveau monde et navigations faictes par Emeric de Vespuce*, 1510), he says correctly, "There is no bright star near the South Pole." In his third voyage he says he has "noted as many as twenty stars as bright as we sometimes see Venus and Jupiter." He gives a sketch of a few stars which cannot be identified. He concludes thus: "I have known many other very beautiful stars which I have diligently noted down, and have described very well in a certain little book describing this my navigation, which at present is in the possession of that most serene King (of Portugal), and I hope he will restore it to me." Vespucci mentions no constellation, and gives no reliable observation.*

Coignet (*Instruction nouvelle touchant l'art de naviguer*, Anvers, 1581) says: "Albericus Vespucius escrit de trois etoilles qui ont leur mouvement à l'entour du Pole Antarctique, faisans ensemble un triangle rectangle, dont le milieu est $9\frac{2}{5}$ degrez du Pole Antarctique." These are possibly the stars β Hydri, β Octantis, and ν Octantis.

Of Andrea Corsali (1517) all we know is contained in two letters given by Ramusio (*Navigationi e viaggi*, 1563–74), in which he exclaims on the wonderful sight of the southern heavens, and describes the two Nubeculæ and the Southern Cross of five stars. He gives a sketch showing Crux and the Nubeculæ with thirteen other stars which cannot be identified. He mentions no other constellation, nor is there any further astronomical reference in his letters.†

* Vespucci states that he observed the new moon on the same day that it was in conjunction with the sun!

† There is much confusion in Houzeau (*Annals of Brussels Observatory*, tome 1), who says that the first grouping of the southern stars was made by the seaman Peter Theodore, and *published* in 1516 by Andrea Corsali.

The Spanish navigator Pedro de Medina (born about 1510) is known in this connection from his work *Arte de navegar*, 1545, of which several editions were published in Spanish, Italian, and French. All in the British Museum have been examined, and the only reference to southern stars is his instruction for determining the latitude in the southern hemisphere by observations of α Crucis, which he says has a "declination" of 30°, by which he means south polar distance. This value for his period is in error about half a degree. No other constellation is mentioned, or any other stars than those in Crux. Other Spanish works on navigation by Rodrigo Zamorano (1581), and Garcia de Palacio (1587), and Clavius (*Sacrobosco Commentarius*, 1585), give similar instructions.

Before considering the question of Petrus Theodorus, it will be convenient to enumerate the southern constellations which were known prior to the first Dutch expedition to the Indies:—(1) Crux, first mentioned by Pigafetta in his journal of Magellan's voyage, 1519, in which he also mentions the two Nubeculæ. (2) The continuation of Eridanus beyond Ptolemy's 34th star to α Eridani, first mentioned by Robert Hues in his *Tractatus de globis*, 1592, in which he says: "There are but three stars of the first magnitude that I could perceive in all those (southern) parts which are never seen in England. The first of them is that bright star in the stern of Argo, which they call Canobus; the second is in the end of Eridanus; the third is in the right foot of the Centaur; to which, if you will add a fourth, the which is fixed on the Centaur's left knee, I shall not much stand against it, but other stars of the first magnitude than those which I have named, that part of the world cannot show us." (3) Columba, a constellation probably made by Plancius out of the unformed stars of Ptolemy's Canis Major. (4) Triangulum Australe, which first appears in Plancius's map of 1594, but the origin of which has not been traced. (5) Polophilax, a large constellation of seven stars given by Plancius (not mentioned by Ideler, *Sternnamen*). This is clearly a group of seven stars which Andrea Corsali shows in the drawing in his letters given by Ramusio. Blundeville (*His Exercises*, 1594), speaking of his celestial globe, says: "Least the South part of this hemisphere or halfe globe should remain void and emptie, I have taken these Southerne Starres of the observation of Andreas Corsalius Florentine, and haue diligently compared the same with the writings of Americus Vesputius and of Petrus Medina, and haue reduced the said starres into this forme or shape. But for so much as I haue seen nothing as yet to my satisfaction or contentment touching the longitude, latitude, magnitude or nature of the said starres." Further on he says: "There are lately found out by the Portugales and others that have sailed in the East and West Indies four other images towards the South Pole, as the Crosse or Croster, the South Triangle, Noah's Dove or Pigeon, and another image made like a philosopher, called Polophilax, all which are set down in the celestial globe lately set forth by M. E. Mullineaux." He adds that the longitude and

latitude of Polophilax "hath not as yet been rightly set down by any that I have read." This shows that Columba, Triangulum Australe, and Polophilax were known before the publication of Plancius's map of 1594. Jodocus Hondius (*Construction and use of the Globes*, 1597, in Dutch) mentions only the remarks of Andrea Corsali.

So far the evidence does not warrant Bayer's attributing any of the southern constellations to Vespucci, Corsali, or Pedro de Medina. He probably made the statement on the authority of the above quotation from Blundeville.

Much uncertainty has existed as to the identity of Petrus Theodorus, and of the extent of his contributions to our knowledge of the southern constellations. His name is given in Latin as Petrus Theodorus F. Embdanus, and in German, Peter Theodors Sohn; but in 1825 Moll, in his work on the early naval expeditions of the Dutch (*Verhandeling over eenige vroegere zeetogten der Nederlanders*), identified him as Pieter Dircksz, or (as the final z stands for zoon) as Pieter Dirckszoon; but he was unable to find any information about him, and he inquires whether this is the same person mentioned by Blaeu as Frederick de Houtman. I find in a Dutch dictionary that the English equivalent of the Dutch name "Dirk" is "Theodoric"; hence, in translating the Dutch name Pieter Dircksz(oon) into Latin, it became Petrus Theodorus F(ilius). From Olbers (*Schumacher Jahrbuch für* 1840) and De Jonge (*De opkomst van het Nederlandsch Gezag in Oost-Indie*, 1862) we learn that his full name was Pieter Dircksz Keyzer. This man was instructed in mathematics and astronomy by Petrus Plancius, who was celebrated as a geographer and for his knowledge of astronomy and nautical matters, and who was one of the principal promoters of the Dutch expeditions to the Indies.

The first expedition of the Dutch to the East Indies sailed from the Texel 1595 April 2. It consisted of four ships, the second of which, the *Hollandia*, commanded by Jan Dignumz, carried Pieter Dircksz Keyzer as chief pilot and head of the steersmen, and Frederick de Houtman as sub-commissioner in the mercantile part of the expedition, with whom we here first become acquainted. From the journals and log of this ship (*Linschoten Vereenigen*, Cornelis Houtman's voyage) and De Jonge (*Opkomst, etc.*) we learn that the *Hollandia* arrived at Madagascar about 1595 September 3,* and stayed there some time. It was here that Pieter Dircksz Keyzer "sought comfort in science, and enriched his knowledge of astronomy by improving the position of old and the observation of new constellations." It must have been at this time that Frederick de Houtman prepared that portion of his vocabulary, referred to below, which deals with the dialect of Madagascar. The ship went on to the Malay Archipelago, and though it is difficult to be certain about dates, it apparently anchored at Achin in Sumatra about 1596 June 5. After three months there it went on to the Straits of Sunda, where on 1596 September 13

* September 25 in Purchas's *Pilgrims*.

Pieter Dircksz Keyzer died. Frederick de Houtman returned in the *Hollandia*, arriving in Holland about 1597 August 10. In the following year, on 1598 March 15, he went out again with a fleet, in command of the ship *De Leeuwin*. The chief pilot of the fleet was John Davis (not to be confounded with John Davis of Dartmouth, the inventor of the Davis Quadrant), and from Davis's journal we learn that the fleet arrived at Achin in Sumatra 1599 June 21. Tiele (*Mémoires sur les voyages Néerlandais*) says that Frederick de Houtman was taken prisoner by the King of Achin in 1598, and kept so for twenty-six months. This can hardly be correct, as he did not arrive there till sometime in 1599. He was, however, for a long time prisoner, and only escaped on 1600 December 31, when he went on board a ship commanded by van Caerden, which was then at Achin. He then returned to Holland. To conclude his career, in 1603 he went out on another voyage as mercantile commissioner, and two years after became governor of Amboyna. I have thus endeavoured to account for all Frederick de Houtman's time, which bears upon the authenticity of his *Catalogue of Stars*.

In 1603 * Frederick de Houtman published at Amsterdam a Malay and Madagascan vocabulary, entitled *Spraeckende woordboeck Inde Maleysche ende Madagaskarche Talen met vele Arabische ende Turksche woorden*. At the end of this work he gives a catalogue of southern stars, the title-page of which is thus translated: "Here follow several fixed stars (observed), with efficient instruments, by Frederick de Houtman, in the island of Sumatra, (their positions) corrected and their numbers increased. For the use and service of those who navigate south of the equinoctial line, also for all amateurs and those who have occasion for the best. These stars are arranged according to their Right Ascension; that is, the degree and minute which a star in the south or north has from where the equinoctial line cuts through (*sic*). Declination is the number of degrees and minutes a star is distant from the equinoctial line towards the South or North Pole. Magnitude is the size of the stars: often a star is of the first size or greatest light: thus there are seven (*sic*) degrees of size and light." In a dedicatory letter to the vocabulary Houtman says: "There will be found at the end the declinations of several fixed stars in the region of the South Pole which I had observed on my first voyage, and which on my second voyage I revised and corrected with more care and brought up to the number of 300, as may be seen on the *Celestial Globe* published by William Jansen (Blaeu)."

This work is extremely rare; every effort that I have made for many years to obtain a copy in Germany, France, Italy, and elsewhere, and by advertising, has failed. Four copies are certainly known, at the British Museum, the Bodleian, the Bibliothèque Nationale, and at Leiden. Thanks, however, to the enterprise of

* Gould is in error in stating that Bayer's *Uranometria* antedated Houtman's *Catalogue*. They were both published in the same year.

Professor Turner, he has had the copy in the Bodleian photographed, and thus this interesting catalogue—the first catalogue of southern stars ever made—is available.*

The catalogue consists of the right ascensions, declinations, and magnitudes of 303 stars, of which 107 stars are found in Ptolemy, leaving 196 newly discovered. The right ascensions are too rough to allow of identification, but by plotting the whole catalogue in a map, and comparing with the maps of the *Uranometria Argentina*, it has been easy to identify nearly every star. The object of the catalogue was to determine declinations for the use of seamen; accordingly, a comparison of the declinations of some fifty stars, with modern observations reduced, is appended.

The new stars are thus distributed:—

Phœnix	13	Volans	5
Corona Australis	7	Chamæleon	9
Eridanus	6	Lupus	14
Hydrus	15	Triangulum Australe	4
Dorado	4	Apus	9
Columba	1	Ara	5
Argo Navis	34	Pavo	19
Centaurus	18	Indus	11
Crux	1	Grus	11
Musca	4	Tucana	6
			196

Was this catalogue made by Frederick de Houtman at Sumatra on the occasions of his two voyages there, as he states?

On his first voyage, then twenty-four years of age, he was in a purely commercial capacity, and there is no record of his being an astronomer or of his having any mathematical ability. Most of his time at Sumatra on both occasions was at Achin, which is in latitude 5° 34′ North; and, as we infer from the ship's journals of the first voyage, he was there on that occasion only some three or four months. The journal of his second voyage is not published, but we have enough information to infer that while at Achin he had but a limited time at his disposal, as he was early taken prisoner by the king and kept in confinement for many months; and unless we assume that during his imprisonment he was able to make astronomical observations, there would have been no sufficient time for an inexperienced man to make the catalogue in question.† How did he determine the right ascensions, rough as they are? In his catalogue he gives the positions of twenty-four

* I had commenced the investigation of this catalogue in 1882, and only after translating some portions of it did I become aware that a translation of the work into French by M. A. Marre had appeared in the *Bulletin des Sciences Mathématiques*, tome v., 1881. I acknowledge several quotations from M. Marre's memoir.

† The dates given by De Jonge (*Opkomst*) for the second voyage do not agree with those in the "Account of Frederick de Houtman at Achin" (*Cort verhael, etc., Gouda*, 1880).

stars, 7 of the 4th, 15 of the 5th, and 2 of the 6th magnitude, whose zenith distances at Achin ranged from 80° to 89° 15′; *obviously he could not have seen them at all.*

It is practically certain that the catalogue used by Bayer was identical with most of Houtman's catalogue, but it contained some additional stars. Blaeu's *Globe*, of which there are two somewhat mutilated examples in the British Museum, is certainly limited to the stars published by Houtman in his vocabulary. According to different authors, the total number of stars in the twelve constellations, Phœnix, Hydrus, Doradus, Volans, Chamæleon, Musca, Apus, Triangulum Australe, Pavo, Indus, Grus, and Tucana are—

Houtman, 1603	112
Bayer, 1603	121
Bartsch, 1624, Text	121
,, ,, Catalogue	131

Kepler, *Tab. Rudolph*, 1627, as Bartsch's catalogue.

Houtman, who was at the time very ill, escaped from prison on 1600 December 31, and he could hardly have got back to Holland before the end of 1601. The preparation of Bayer's *Uranometria* would take considerable time, and it is highly probable that he possessed the materials for his maps some time before Houtman's return. Whence did he obtain those materials?

Pieter Dircksz Keyzer, who was versed in mathematics and astronomy, and was held in high estimation by the Dutch East India Company, would have a favourable opportunity during the long stay of the *Hollandia* at Madagascar, from 1595 September to April or May of 1596, to make observations and to chart the new constellations. As Merula says: "sedens ibi in corbe, vel ut vocant nonnulli, galea." In that latitude he could quite well observe 5th and 6th magnitude stars near the South Pole. For the right ascensions we may surmise that Plancius would furnish him with some of Tycho Brahe's observations, from which they might be roughly derived; certainly there was no other material available for the purpose. I have failed to find any information as to relations between Tycho Brahe and Plancius.

Frederick de Houtman was in Pieter Dircksz's company all the time, but as commissioner he would be engaged in the development of trade, and, moreover, he was then collecting materials for his Malay and Madagascan vocabulary. Though all the evidence is circumstantial, the following inferences are irresistible: that the whole catalogue and the formation of the new twelve constellations must be attributed to Pieter Dircksz Keyzer, and not in any way to Frederick de Houtman: that the catalogue was sent back by the *Hollandia*, and after the return of that ship on 1597 August 10 it would go to Plancius, who probably communicated it to Bayer: and that Frederick de Houtman obtained an imperfect copy of it which, as Pieter Dircksz was dead, he published as his own work in the above-mentioned vocabulary.

Since coming to this conclusion I learn, a few weeks ago, from a high authority in Holland, that the opinion there at the present time is to the same effect, and that the Linschoten Society contemplate publishing a full account of Pieter Dircksz Keyzer.

In either case the whole merit of the discovery and formation of the constellations must be attributed to the Dutch.

The catalogue gives the descriptions of the stars, which I have translated from the Dutch, and compared with the translation of M. Marre. The modern designations are from the *Uranometria Argentina*, and the magnitudes from that work are appended.

In the table which follows, the declinations of fifty stars are compared with Neugebauer's *Sterntafeln*. No information can be found as to the instruments used, which were probably limited to the astrolabe and quadrant. With such instruments the comparison shows that some of the observations were very good.

Catalogue of Stars given in Frederick de Houtman's Malay and Madagascan Vocabulary.

No. and Description.	No. and Name. *Uranometria Argentina.*	Magnitude. H.	Magnitude. U.A.	R.A.	Decl.
The bird Phœnix has 13 *stars.* *Phœnix.*					
1. The most northern star in the flame	16 Sculptoris β*	5	4·8	347° 20′	40° 50′
2. The middle one in the flame	11 Phœnicis	5	4·5	348 35	44 15
3. The most southern star in the flame	9 ,, ι	4	4·4 *v*	349 45	42 45
4. One in the right wing	39 ,, ϵ	4	3·8	357 10	47 45
5. A star in the neck of the bird Phœnix	48 ,, α	2	2·4	1 0	44 5
6. One in the neck	46 ,, κ	4	3·9	1 30	45 34
7. One in the body of Phœnix	54 ,, λ^1	4	4·6	2 40	50 15
8. One in the breast	64 ,, μ	4	4·7	4 30	47 30
9. One below the right foot, in the wood	68 ,, η	4	4·5	7 20	59 30
10. One below the left wing, in the flame	85 ,, β	3	3·3	11 20	49 20
11. One below the left foot, in the wood	89 ,, ζ	4	4·2	13	57 0
12. At the end of the left wing	106 ,, γ	3	3·4	18	44 45
13. One below the same wing, in the fire	109 ,, δ	3	4·0	19 30	51 25
The Southern Crown has 16 *stars.* *Corona Australis.*					
1. The most western star in the crown	15 θ	4	5·1	269 18	41 45
2. The second following it	13	5	5·6	270	40 15
3. The third ,,	16 κ	5	5·4	270 10	39 18
4. The fourth ,,	18	5	5·8	271 26	43 16
5. The fifth ,,	25 η^1	5	5·7	273 28	44 10
6. The sixth ,,	32	5	6·6	275 36	45 20
7. The seventh ,,	30	6	5·8	276 30	43 30

* The positions of 1, 2, and 3 Phœnicis are erroneous; Bayer gives correctly the identified stars.

Catalogue of Stars given in Frederick de Houtman's Malay and Madagascar Vocabulary—continued.

No. and Description.	No. and Name. *Uranometria Argentina.*	Magnitude. H.	Magnitude. U.A.	R.A.	Decl.
				° ′	° ′
8. The eighth following it	39 ζ	5	5·2	277 35	43
9. The ninth ,,	43 δ	4	5·0	278 40	42 2
10. The tenth ,,	46 β	4	4·1	279 45	40 35
11. The eleventh ,,	44 α	4	4·2	280 30	38 50
12. The twelfth ,,	41 γ	5	4·6	280	37 30
13. The thirteenth ,,	34 ϵ	5	5·5	277 37	37 40
14. The fourteenth ,,	19 λ	5	5·4	274	38 20
15. The fifteenth ,,	20	5	5·6	274 25	40
16. The last star in the crown	24 μ	5	5·5	274 50	41
The southern end of the Nile, with corrections and additions. 7 *stars.*					
Eridanus.					
1. Acarnar, the end of the Nile	2 α	1	1·0	20 50	59 20
2. The first star following	7 χ	4	3·9	25 20	54 30
3. The second ,,	14 φ	4	3·5	31 25	53 45
4. The third ,,	16 κ	4	4·2	33 50	49 30
5. The fourth ,,	18 S	4	5·0	35 40	44 24
6. The fifth ,,	19 ι	4	4·2	37 24	41 28
7. The sixth following in the Nile	48 θ	3	2·6	41 20	41 50
The Water-snake has 15 *stars.*					
Hydrus.					
1. The head of the water-snake	24 α	2	2·9	26	63 30
2. One star in the neck	32 Horologii β	5	5·2	38 23	65 0
3. The second following	47 Hydri ζ	5	5·2	41 38	68 25
4. The third ,,	44 ,, ϵ	5	4·2	39 50	69 18
5. The fourth ,,	38 ,, δ	5	4·1	34 45	70
6. The fifth is above the small nebula (Nubecula minor)	70 Tucanæ λ^2	5	5·5	16 50	71 45
7. The sixth following	50 ,, π	5	5·7	10 27	72 15
8. The seventh ,,	47 ,,	5	6·8	4 30	75 10
9. A star above the preceding one.	45 ,,	5	5·9	356 42	74 6
The small nebula	Nubecula minor	...	...	14 25	75
10. The ninth following	5 Hydri β	4	2·7	4 30	80 12
11. The tenth ,,	88 Octantis θ	6	5·4	359	79 30
12. The eleventh situated in the tail	75 ,, β	4	4·4	332 45	83 40
13. The end of the tail	60 ,, ν	4	3·8	312 34	78 46
14. One before the breast of the water-snake	14 Reticuli β	4	3·9	56	65 45
15. One situated below the last	62 Hydri γ	4	3·2	62 30	74

Catalogue of Stars given in Frederick de Houtman's Malay and Madagascar Vocabulary—continued.

No. and Description.	No. and Name. *Uranometria Argentina.*	Magnitude. H.	Magnitude. U.A.	R.A.	Decl.
Doradus has 4 stars.					
1. The extremity of the tail	8 α	3	3·1	62° ′	53° 20′
2. One below the fin, near the tail	20 ζ	3	4·8	67 50	56 26
3. One above the body	29 β	3	3·9	85 20	61 54
4. One below, near the mouth	33 δ	3	4·5	87 33	65 12
The Dove with the Olive Branch. Columba.					
1. The right (? left) wing	22 ε	5	4·1	79 40	36 18
2. The bright star in the body	38 α	2	2·5	82 0	34 25
3. One under the left wing	41	5	6·4	82 40	31 54
4. The right shoulder	53 β	2	2·9	84 0	36 10
5. The right wing	57 λ	5	5·2	84 45	34 15
6. One in the neck	65 γ	5	4·5	86 15	36 0
7. One in the beak	79 θ	5	5·3	90 40	37 50
8. The southern end of the olive branch	66 η	5	5·8*v*	86 5	42 30
9. One above the head, in the olive branch	84 κ	5	4·8	91 40	35 0
10. The second one above this	91 δ	5	3·9	92 50	33 20
11. The most northern of these	35 Canis Maj. λ	5	4·7	93 42	32 15
Argo Navis. The Ship.					
1. The sounding line	32 Pictoris β	5	3·9	84 32	51 42
2. One in the water, behind the rudder	35 ,, γ	3	4·7	87 20	56 10
3. One below the rudder	48 ,, δ	4	5·2	91 10	54 12
4. Canopus, the brilliant star in the rudder of the ship	7 Carinæ α	1	0·4	93 40	52 15
5. One in the hand of the steersman	20 Puppis ν	4	3·5	95 45	42 14
6. One behind this, in the stern gallery	39 ,, τ	4	3·2	99 25	49 55
7. One in the stern of the ship	18 Carinæ A	3	4·8	99 30	52 35
8. One behind this, below the ship	66 Pictoris α	4	3·5	100 15	61
9. One in the mizen-mast	99 Puppis σ	5	3·5	110 12	42 20
10. One above this, in the mizen-shrouds	162 ,,	6	5·7	111 40	37 0
11. One in the mizen-yard	213 ,, *a*	4	4·0	113 45	34 30
12. One above, in the mizen-top	214 ,, *b*	5	4·9	115 30	30 25
13. One at the end of the main drift,* against the main shrouds	65 Carinæ κ	3	3·7	115 40	52 20

* 13. Argo. The Dutch word here is "fortuning," which in modern Dutch is "vertuining," and means the old shipbuilders' term "drift," where the sheer is raised and the rail cut off: here it is the main-drift. Argo in the catalogue is a three-masted ship.

Catalogue of Stars given in Frederick de Houtman's Malay and Madagascar Vocabulary—continued.

No. and Description.	No. and Name. *Uranometria Argentina.*	Magnitude. H.	Magnitude. U.A.	R.A.	Decl.
14. One at the ridge of the main yard	248 Puppis ζ	3	2·5	116° 30′	*32° 0′
15. One in the bolt-rope of the main-sail	267 ,, h^1	5	4·8	117 10	38 15
16. One other near this	279 ,, h^2	5	4·8	117 20	39 40
17. One in the main-rigging	9 Velorum γ	3	3	119 30	46 25
18. One in the fore-shroud	56 ,, o	4	4·0	124 50	51 40
19. One in the main-mast	48 ,, e	5	4·6	125 40	42 12
20. A small star below this	58 ,, n	6	5·2	125 45	47 0
21. Another small star near this	53 ,, b	5	4·1	126 35	45 30
22. One in the main-sail	66 ,, a	5	4·1	129 0	45 0
23. One above this	64 ,, d	5	4·4	129 30	41 26
24. Another one before this	97 ,, c	4	4·6	132 12	45
25. One above in the sail	100 ,, λ	3	2·5	135 18	42 2
26. One in the main-top	22 Pyxis β	5	4·4	128 20	34 5
27. One at the top of the main-mast	24 ,, α	5	3·8	129 15	31 34
28. One in the main-top mast	36 ,, γ	5	4·4	131 0	26
29. One in the ship, before the main-mast	89 Carinæ ϵ	3	2·1	123 10	58 20
30. One below the main-sail, before the mast	65 Velorum δ	3	2·2	127	53 45
31. One in the rail below the main-sail	127 Carinæ ι	3	2·5	136 20	57 30
32. Another one near the preceding	117 ,, a	4	3·8	134 36	57 28
33. One in the bolt-rope of the sail	129 Velorum κ	3	2·7	137	53 45
34. One below the belly of the sail	144 ,, N	5	3·2	139 25	55 31
35. One below this, in the forecastle	147 Carinæ h	5	4·9	139 50	57 46
36. Another below this, near the shrouds	150 ,, m	5	5·1	140 30	59 10
37. Another below the shrouds	157 ,, l	5	3½–5 v	142	60 35
38. One below the ship	123 ,, β	3	2·0	138	67 30
39. One on the bend-wale, below the anchor	160 ,, ν	3	3·3	143 45	63
40. One in front, below the keel of the ship	185 ,, ω	3	3·6	150 46	68 2
41. One below this	193 ,, I	4	4·4	153 30	71 50
42. One in the stern of the ship	223 ,, θ	3	2·9	155 40	62 20
43. One in the anchor	187 ,, q	5	3·3–4·5 v	149 30	59 30
44. One above the anchor-stock	196 ,, s	4	4·6	151 53	56 50
45. Another in the anchor-stock	203 ,, p	4	3·6	152 54	59 46
46. One above the foresail	204 Velorum r	6	5·3	151	41 23
47. One above, in the foremast	191 ,, q	4	4·0	149 50	41 26
48. One below this, in the shrouds	?	5	...	148 35	42 34
49. Another one below this	193 Velorum	6	6·2	149	44

* 14. Argo. The declination is probably a misprint for 38° 0′.

Catalogue of Stars given in Frederick de Houtman's Malay and Madagascar Vocabulary—continued.

No. and Description.	No. and Name. *Uranometria Argentina.*	Magnitude. H.	Magnitude. U.A.	R.A.	Decl.
50. One in the middle of the foresail	216 Velorum *s*	5	5·4	153° 10′	45° 20′
51. One other near this	218 ,,	6	6·4	152 12	45 36
52. One more near this	219 ,, *t*	5	5·6	155 36	45 50
53. One in the fore-sheet	222 ,, *p*	4	4·1	157 30	46 16
54. One below this	229 ,, μ	4	2·9	158 40	48
55. One below, in the foresail	215 ,, *x*	5	5·6	155 46	52 30
56. One below the bowsprit	246 Carinæ *u*	5	4·1	159 30	56 50
Centaurus.					
1. One below, in the tail of Centaurus	260 Carinæ *x*	5	4·6	163 15	57 10
2. The bright star in the tail	24 Centauri π	4	4·3	166 55	52 26
3. One other next to this	42 ,, A	5	5·2	170 0	52 15
4. One near the hind-foot of Centaurus	46 ,, λ	4	3·4	170 25	61
5. One below, near the foot	15 Muscæ λ	4	3·8	172 30	64
6. Another one near this	16 ,, μ	6	5·3	173 0	64 30
7. Another one following	69 Centauri *j*	5	4·9	172 35	61 45
8. Another one following	18 Muscæ	5	5·5	174	63
9. Another one in the hind-foot	6 Crucis θ	5	4·7	176 40	61
10. One below this	10 ,, η	5	4·7	177 35	62
11. One in the foot of the Cross	19 ,, ζ	5	4·6	179 34	61 35
12. One above, in the leg of Centaurus	94 Centauri δ	3	2·8	178 15	48 18
13. One below this	101 ,, ρ	5	4·5	179	50
14. One in the belly of Centaurus	121 ,, σ	5	4·3	182 24	47 36
15. A small star near this	119 ,, G	6	5·7	182	48 30
16. One in the body of Centaurus	134 ,, γ	3	2·4	186 12	46 48
17. One above this, in the body	131 ,, τ	5	4·4	185	46 25
18. Another one in the body	149 ,, *e*	5	5·0	188 50	46 15
19. Another one below, in the body	142 ,,	5	6·2	190	49 10
20. One above the preceding	156 ,, H	5	5·8	190 30	48
21. Another one there above	165 ,, ξ^1	5	5·8	190 45	46 12
22. The uppermost in the body	171 ,, *f*	5	5·3	191 10	45
23. One below this in the body	173 ,, ξ^2	5	4·8	192 43	46 20
24. The left shoulder	204 ,, ι	3	3·0	194 40	34 0
25. One below this	227 ,, *d*	4	4·5	196 55	37 20
26. One in the head of Centaurus	265 ,, *i*	5	4·5	200 30	30 40
27. The most northern star in the head	284 ,, *h*	5	5·2	202	29 35
28. One other below this	280 ,, *k*	5	4·7	201 28	30 32
29. Also another below this	274 ,, *g*	5	4·6	201 20	32 10

Catalogue of Stars given in Frederick de Houtman's Malay and Madagascar Vocabulary—continued.

No. and Description.	No. and Name. *Uranometria Argentina.*	Magnitude. H.	Magnitude. U.A.	R.A.	Decl.
30. One above in the right leg	245 Centauri ϵ	3	2·6	199° 50′	51° 15′
31. One on the back of this (constellation)	273 ,, μ	4	3·4	200 20	41 8
32. One above this, on the back	272 ,, ν	4	3·7	200 35	39 58
33. Another one near this	296 ,, ϕ	4	4·1	203 8	40 30
34. Another one following	311 ,, χ	4	4·8	205 16	39 40
35. One in the belly	289 ,, ζ	3	2·7	202 18	45 20
36. One above in the right side	297 ,, υ^1	4	4·2	203 15	43
37. Another one near this	303 ,, υ^2	5	5·0	204 10	44
38. One in the left leg of Centaurus	304 ,, β	2	1·2	204 20	58 8
39. One in the right foot of Centaurus	363 ,, α	1	0·7	213 48	58 48
40. One below this, near the foot	17 Circini α	3	3·5	210 50	62 30
41. The right shoulder	314 Centauri θ	3	2·2	206 15	35
42. One in the flag (of the lance)	338 ,, ψ	4	4·4	208 40	36 0
43. One below this, in the lance	342 ,, α	4	4·9	209 10	37 35
44. One above, in the flag	371 ,, c^1	4	4·3	214 30	33 20
45. Another one below this	368 ,, b	4	4·2	215 35	35 30
46. One in the right arm	356 ,, η	4	2·5	213 50	41 20
47. One in front, in the same arm	41 Lupi β	4	2·8	217 40	41 18
48. One below this, in the arm	385 Centauri κ	4	3·3	217 45	40 38
Crux.					
1. The western arm of the Cross	18 δ	3	3·4	179 35	56 26
2. One below this	22 ϵ	5	4·0	180 20	58 25
3. The lowest star, or foot of the Cross	26 α	2	1·3	182 25	60 40
4. The head of the Cross	34 γ	3	2·0	183	54 48
5. The eastern arm of the Cross	46 β	3	1·7	186	57 8
Musca.					
1. One below, in the body	44 γ	4	4·0	182 55	69 50
2. One above, in the left wing	45 α	4	2·9	184 10	66 30
3. The head	51 β	4	3·4	186 8	65 20
4. The right wing	54 δ	4	3·7	189 25	69 10
The Flying Fish.					
Volans.					
1. One in the tail of the Flying Fish	10 δ	4	4·1	111 16	67 30
2. Another one below this	9 γ^2	4	3·8	111 18	68 32
3. The right wing	16 ζ	4	4·3	119	71 15
4. The left wing	22 ϵ	4	4·5	122 46	67 33
5. One in the neck	25 κ^1	4	4·7	127 10	70

Catalogue of Stars given in Frederick de Houtman's Malay and Madagascar Vocabulary—continued.

No. and Description.	No. and Name. *Uranometria Argentina.*	Magnitude. H.	Magnitude. U.A.	R.A.	Decl.
Chamæleon.					
1. The end of the tail	5 θ	5	4·7	130° 30′	74° 30′
2. One above this, the second in the tail	4 α	5	4·2	128 26	73 40
3. The third in the tail	8 η	5	5·6	140	76 20
4. The fourth in the tail	13 ι	5	5·8	148	77
5. The fifth in the tail	14 ζ	5	5·5	150 34	77 15
6. The most northern star in the back	23 γ	5	4·4	158	75 30
7. One below this, in the body	26 δ^2	5	4·9	161 30	77 25
8. Before the shoulder	37 ϵ	5	5·0	176	74 50
9. One below this, before the body	40 β	5	4·6	179 40	76 20
Lupus.					
1. One in the tail	332 Centauri	5	6·7	208 30	44 25
2. One other above this	2 Lupi	5	6·3	208 35	43 26
3. Another near this	3 ,,	5	5·7	209 40	44 10
4. One at the end of the tail	9 ,, τ^1	6	5·3	210 34	43
5. Another near this	10 ,, τ^2	6	4·9	211	43 15
6. One in the right foot	27 ,, α	4	2·6	213 35	46
7. One other below this	20 ,, ρ	5	4·5	212 45	47 30
8. Another below the preceding	15 ,, σ	5	5·2	*211 15	48 32
9. One in the left buttock	30 ,, b	5	5·8	215 30	50 52
10. One other near this	42 ,,	5	6·7	218 33	50 45
11. One above, in the left thigh	64 ,, ζ	4	3·6	221 45	50 12
12. One behind, on the hip	44 Circini β	5	4·7	221 42	56 45
13. Another one near this	47 ,, γ	5	5·2	223 32	57 15
14. One below this	42 ,, δ	5	5·6	221 28	59 10
15. Another one, a small star, near this	45 ,,	6	5·9	222	58 30
16. One in the belly	47 Lupi π	4	4·3	219 25	45
17. One below this, in the belly	62 ,, κ	4	4·1	221	46 50
18. One above this, in the belly	57 ,, λ	4	4·8	221 30	44
19. Another one in the belly	75 ,, μ	4	5	222 55	46 30
20. Another one near this	86 ,, υ^1	6	5·8	223 5	47
21. One at the front of the left hip	83 ,, δ	4	3·7	223 30	39 55
22. The heart of the wolf	91 ,, ϵ	4	3·7	224 20	43 40
23. Another one in the body	114 ,, d	5	5·1	227	43 45
24. One at the front of the shoulder	113 ,, γ	4	3·2	227 30	40 16
25. One below this	117 ,, ω	5	4·7	227 56	41 25

* 8. Lupi, right ascension given erroneously by Marre as 211° 11′.

Catalogue of Stars given in Frederick de Houtman's Malay and Madagascar Vocabulary—continued.

No. and Description.	No. and Name. *Uranometria Argentina.*	Magnitude. H.	Magnitude. U.A.	R.A.	Decl.
26. Another one below this	121 Lupi g	5	5·2	228° 15′	43° 30′
27. Another one near this	115 ,,	5	6·2	227 25	43 25
28. One in the neck	146 ,, η	4	3·7	233 12	37 20
29. Another one near there	157 ,, θ	6	4·9	235	35 30
Triangulum Australe.					
1. The southern angle	5 γ	3	3·1	219 20	66 48
2. One above this	11 ϵ	5	4·6	222 50	64 32
3. The northern angle	17 β	3	3·1	226 18	62 10
4. The apex of the triangle	42 α	2	2·2	238 45	68
The Bird of Paradise.					
Apus.					
1. One in the foot, by the tail	19 Octantis δ	4	4·7	206 50	80 35
2. One in the tail	6 Apodis η	4	5·3	207 10	77 40
3. Another one near this	9 ,, ϵ	6	5·5	209 8	76 45
4. Another one above this	14 ,, α	4	4·0	212 45	76 26
5. One at the end of the body	40 ,, δ^1	5	5·2	228 40	76 10
6. One below this	44 ,, γ	5	3·9	229 30	77
7. Another one near this	47 ,, β	5	4·5	234	76 20
8. One in the neck	33 Octantis ϕ	5	5·8	261 30	75 25
9. One in the beak	41 Pavonis	5	6·2	271	72 12
Ara.					
1. The west foot of the altar	13 η	4	3·8	241 10	57 30
2. The western part of the upper edge	23 ζ	4	3·2	244	54 40
3. The western part of the flame	25 ϵ^1	4	4·2	245 46	52
4. The eastern part below, in the altar	60 δ	4	3·7	248 32	60 30
5. The eastern part above, in the altar	50 γ	4	3·6	249 42	56 32
6. The eastern part below, in the flame	51 β	4	2·8	250	55
7. One there following, in the flame	62 α	4	2·9	255	49 38
8. The fourth star in the flame	84 θ	4	3·9	262 30	49 35
9. The fifth star in the flame	3 Telescopii ϵ	4	5·2	265 8	46 10
10. The sixth star in the flame	14 ,, ζ	4	4·5	269 20	49
11. The seventh star in this flame	13 ,, α	4	3·5	269 25	46 20
12. The last in this (constellation)	16 ,, δ^1	6	5·7	270 15	46 30
The Tail of Scorpius.					
1. The first, in the tail	98 μ^1	3	3·2	246 30	37 10
2. The second, in the tail	103 ζ	3	5·8	247	41

Catalogue of Stars given in Frederick de Houtman's Malay and Madagascar Vocabulary—continued.

No. and Description.	No. and Name. *Uranometria Argentina.*	Magnitude. H.	Magnitude. U.A.	R.A.	Decl.
3. The third, in the same	104 ζ^2	3	3·6	247° 10′	41° 36′
4. The fourth in this	126 η	3	3·6	252 18	42 32
5. The fifth in this	160 θ	3	2·1	257 30	42 38
6. The sixth, in the tail	169 ι^1	3	3·3	260	39 50
7. The seventh in this	165 κ	3	2·6	258 35	38 45
8. The eighth of this	156 λ	3	2·0	256 34	37
9. The last of the tail of Scorpius					
Pavo.					
1. A star at the extremity of the tail	2 η	4	3·8	252 50	64 40
2. One following, in the same	16 π	5	4·6	259 48	64 10
3. The uppermost, in the same	26 ξ	5	4·4	265 5	62 30
4. One below this	32 ν	6	6·0	266 20	63 50
5. One below this	39	5	5·3	267 22	65
6. One other in the same tail.	45 λ	5	4·3	271 45	63 28
7. One below this	46 κ	5	4·0–5·6v	270 30	66 5
8. One other below the preceding	43 θ	6	6·1	270 32	67
9. One at the extremity of the body	56	5	5·7	274 30	69
10. One in the right foot of Pavo	78 ϵ	4	4·0	280 50	73 45
11. One above, in the body	88 δ	3	3·5	290 30	67 30
12. One below this	83 μ^2	5	5·6	289 20	68 15
13. The head	99 α	2	2·1	297 15	58 14
14. One in the neck	104 ϕ^1	5	4·9	299 30	62 30
15. One below this	107 ρ	5	4·9	300 40	64
16. Another one in the neck	109 ϕ^2	5	5·5	301 50	62 33
17. The heart	6 Tucanæ δ	3	4·8	330 36	68
18. One below this	110 υ	5	5·6	*309 45	68 40
19. The breast of Pavo	111 β	3	3·3	311 52	68 30
Indus					
1. The fore-end of his spear	78 Telescopii ξ	5	5·5	291 15	55 16
2. One in the right shoulder	2 Indi η	5	4·7	304 20	54 20
3. One near this, in the shoulder	5 ,, ι	5	5·6	305 30	54 16
4. Another one near this	8 ,,	5	6·0	306 28	54 15
5. One below the belly	6 ,, β	4	3·7	305 30	60 20
6. One in the chest	12 ,, μ	5	5·8	306 40	56 45
7. One in the head	?	4		310 28	52 35

* 18 Pavonis. Misprint of 209° for 309° in the Right Ascension.

Catalogue of Stars given in Frederick de Houtman's Malay and Madagascar Vocabulary—continued.

No. and Description.	No. and Name. *Uranometria Argentina.*	Magnitude. H.	Magnitude. U.A.	R.A.	Decl.
8. The left shoulder	?	4		313° 40′	54° 26′
9. One in the upper part of the spear	?	4		319 45	55 22
10. One in the middle part	60 ,, δ	4	4·8	323 30	56 12
11. One in the lower part	64 ,, ϵ	4	5·2	323 37	57 25
The Heron.					
Grus.					
1. The head of the heron	18 γ	2	3·0	322 44	39
2. One in the neck	27 λ	4	4·7	325	41 5
3. The left wing	28 α	2	1·9	326 25	49
4. The second, in the neck	35 μ^1	4	5·0	327	43 25
5. The third, in the neck	43 δ^2	4	4·4	329 45	45 40
6. One near this	42 δ^1	5	4·2	329 15	45 35
7. The heart	57 β	2	2·2	335 12	49
8. One in the left leg	61 η	4	5·1	335 40	55 45
9. One above this, in the leg	68 ϵ	4	3·5	336 30	53
10. One in the tail	77 ζ	4	4·0	340 40	54 10
11. One in the right wing	84 θ	4	4·2	341 20	46 12
12. One other below this, in the wing	90 ι	4	3·9	341 50	48
The Indian Magpie, named by the Indians Lang.					
Tucana.					
1. One above, on the beak	26 γ	4	4·0	344	60 15
2. One in the body	?	5		351 20	65 30
3. Another one in this	43 η	5	5·9	353 10	66 36
4. One behind, in the left leg.	44 ϵ	5	4·3	355 35	68
5. One at the extremity of the body	49 ζ	5	4·1	0	67 24
6. One in the tail *	52 β	5	4·3	2 50	64 34

Comparison of Houtman's Declinations for Epoch A.D. 1600.

Star.	Houtman.	Neugebauer.	N.–H.
α Phœnicis	−44° 5′	−44° 30′	−25′
α Eridani	59 20	59 17	+ 3
θ ,,	41 50	41 56	− 6
α Columbæ	34 25	34 20	+ 5

* The position of 6 Tucanæ is correctly identified as 52 β, but it is not the star in the tail.

Comparison of Houtman's Declinations for Epoch A.D. 1600—continued.

Star.	Houtman.	Neugebauer.	N.–H.
α Argus	52° 15′	52° 30′	−15′
τ Puppis	49 55	50 11	−16
σ ,,	42 20	42 32	−12
ζ ,,	32 0?	38 55	
γ Velorum	46 25	46 11	+14
ϵ Carinæ	58 20	58 15	+ 5
δ Velorum	53 45	53 17	+28
λ ,,	42 2	41 52	+10
β Carinæ	67 30	68 5	−35
ι ,,	57 30	57 38	− 8
κ Velorum	53 45	53 20	+25
N ,,	55 31	55 17	+14
υ Carinæ	63 .	63 14	−14
θ ,,	62 20	62 19	+ 1
μ Velorum	48	47 19	+41
α Crucis	60 40	60 52	−12
γ ,,	54 48	54 52	− 4
β ,,	57 8	57 29	−21
δ Centauri	48 18	48 29	−11
γ ,,	46 48	46 45	+ 3
ι ,,	34 0	34 35	−35
ϵ ,,	51 15	51 24	− 9
ζ ,,	45 20	45 17	+ 3
β ,,	58 8	58 23	−15
θ ,,	35	34 22	+38
α Lupi	46	45 37	+23
α Centauri	58 48	59 7	−19
α Muscæ	66 30	66 55	−25
β Lupi	41 18	41 26	− 8
γ ,,	40 16	39 45	+31
η ,,	37 20	37 10	+10
γ Trianguli Austr.	66 48	67 3	−15
α ,,	68	68 9	− 9
μ^1 Scorpii	37 10	37 17	− 7
ζ^2 ,,	41 36	41 35	+ 1
η ,,	42 32	42 37	− 5
λ ,,	37	36 43	+17
θ ,,	42 38	42 38	0
κ ,,	38 45	38 44	+ 1

Comparison of Houtman's Declinations for Epoch A.D. 1600—continued.

Star.	Houtman.	Neugebauer.	N.–H.
	° ′	° ′	′
ι^1 Scorpii	39 50	39 53	− 3
ζ Aræ	54 40	55 14	−34
β ,,	55	55 2	− 2
α ,,	49 38	49 26	+12
α Pavonis	58 14	57 55	+19
α Gruis	49	48 51	+ 9
β ,,	−49	−48 57	+ 3

The Number of Stars of Different Magnitudes in the Hyderabad Astrographic Catalogue, Zone − 17°. By R. J. Pocock, B.A., B.Sc.

1. The first volume of the *Hyderabad Astrographic Catalogue*, containing the diameters and measured co-ordinates of over 63,000 stars on plates with centres approximately in Decl. − 17°, is now completed. The numbers of stars recorded under different diameters have been counted, and the results are discussed in the present note. As the printing of the volume is not yet complete, it may be best to begin with a brief description of the Hyderabad practice in determining diameters.

2. As each star is measured an estimate of the diameter is made and entered on the measure sheets. Since each star is measured twice in different positions of the plate; two estimates of the diameter are made, and these are added together and the sum printed in the catalogue under the heading d (thus following the Greenwich plan). In order to convert these numbers into magnitudes a formula of the form $m = a - b\sqrt{d}$ has been adopted, since other observatories have found such a formula suitable. The numbers of stars of each tenth of a magnitude among the reference stars used for this zone, taken from the *Washington A.G. Catalogue*, were counted, and by means of these counts the Washington magnitudes were converted to a scale comparable with that of Chapman and Melotte.* These modified magnitudes (m) were then compared with the diameters (d) separately for each plate, and hence the constants a, b determined. Several different groups of plates gave values of b all close to 1·09, which was therefore adopted for the whole zone, and the values of a determined separately for each plate. The resulting formulæ, however, very often result in giving much too faint a magnitude for the fainter stars on the plate. This is due to the fact that most of the measurers used in reality two distinct scales, one for the bright stars and another for the faint stars, estimating all the stars as over 20 or under 10 say, with very few between, so that a formula determined

* See *Astronomical Journal*, vol. xxix., No. 688.

from the bright stars alone necessarily makes the faint stars too faint, and *vice versâ*. We shall have evidence of this fact later. Another peculiarity is that some of the measurers estimate a very large proportion of their stars as 4 or 5 (printed as 8 or 9); on the other hand, other measurers go to the other extreme, and never use these low numbers at all. Since there were five different measurers working throughout, and six towards the end of the work, and the work of the different measurers is well mixed up in each part of the zone, this can have little effect on the final counts.

3. Since one of the objects of this paper is to look for discontinuities in the ratio of faint to bright stars, it is well to consider first what artificial discontinuities may exist, owing to seasonal changes, etc. The zone here considered is particularly favourable for such a consideration; the whole work occupied just two years (1914 Dec.–1916 Dec.), and only two different batches of plates were used. In the earlier part of the work (1914 Dec.–1915 May) the plates used belonged to an old batch that had been in India for some considerable time, and had lost much of their sensitiveness. The exposures given were at first fifteen minutes, and towards the end of this period were increased to eighteen and in a few cases to twenty minutes. All the plates from three hours to ten hours belong to this group, as also a few plates outside these limits of R.A. Since this region was taken within a comparatively short period of time and with similar plates, there is little likelihood of the artificial introduction of any discontinuity in the series. With a few exceptions (mostly in $11^h - 13^h$) all the plates from 10^h to 3^h were taken between 1916 March and 1916 December with a different batch of plates. A few of these newer plates were given an exposure of fifteen minutes, but as they were found to be much more rapid than the older ones, the exposure was soon diminished to twelve minutes. The great majority of these plates were exposed during the period 1916 March 1–1916 May 7, while of the plates exposed later in the year, most were exposed in October–November. Hence here again there is very little chance of any discontinuity. It is true that in the period December–March there is a very great rise in temperature, but this occurs slowly and should cause no sudden break. There is, on the other hand, a sudden change about the middle of June, when the monsoon sets in, but in June, July, or August it is very rarely possible to secure plates, and there are very few in this volume taken in these months.

4. Turning to the numbers themselves, and denoting by N_x the number of stars whose recorded diameters (*i.e.* the sum of two estimations) are not less than x, I have tabulated in Table I. the totals for each hour of R.A. of N_{50}, N_{30}, N_{20}, N_{12}, N_8, the latter being equal to the total number of stars measured. Since the hours of R.A. contain alternately eight and seven plates, the numbers have first been multiplied by a factor to make them equivalent to ten plates in each hour of R.A.

TABLE I.

Cumulative Totals for Ten Plates in each Hour of R.A., Zone − 17°.

R.A. h	N_{50}	N_{30}	N_{20}	N_{12}	N_8
0	93	553	909	1413	1940
1	60	379	656	1075	1620
2	53	366	726	1313	1777
3	59	308	729	1272	1665
4	94	353	832	1500	2310
5	248	1121	1841	2694	3270
6	236	1016	2059	3383	4620
7	164	1108	3100	6401	10720
8	123	724	1554	3067	5220
9	79	378	871	1610	2750
10	51	259	554	1116	1966
11	51	252	581	1182	2341
12	69	316	613	1249	1974
13	100	434	799	1520	2799
14	107	637	1180	2044	3990
15	106	514	1151	2220	4236
16	119	494	821	1490	2917
17	182	739	1356	2720	5910
18	110	611	1214	2490	6167
19	91	330	1046	2189	5282
20	89	587	1206	2273	4034
21	108	708	1146	1864	2620
22	87	429	820	1376	2203
23	64	446	789	1261	1861
C. and M. Mag.	9·14	10·77	11·55	12·25	12·94
Calcd.	9·16	10·62	11·51	12·40	12·95
Diff.	−·02	+·15	+·04	−·15	−·01

5. The most noticeable feature about the table is the sudden very large increase in the star density between 6^h and 7^h, which, moreover, the table shows is entirely due to the fainter stars. At the foot of each column is given the corresponding magnitude on the C. and M. scale, determined from the table in *Monthly Notices*, vol. lxxv. p. 145. Below these are given the magnitudes calculated from the formula $m = 15{\cdot}44 - 0{\cdot}88\sqrt{d}$. Now the value of b, viz. 0·88 in this formula, is sensibly different from that mentioned above, viz. 1·09, adopted for the whole zone. It will be seen that the formula just given suits very well both for faint and bright stars, whereas if we use the value 1·09 and only take account of the bright stars we obtain the formula $16{\cdot}92 - 1{\cdot}09\sqrt{d}$, which will

make the faint stars 13·84 instead of 12·95, nearly a whole magnitude too faint; this is an instance of the fact mentioned above, that the bright stars are estimated too bright relatively to the faint stars. The formulæ given in the printed volume must therefore be considered as only suitable for the bright stars; at about mag. 11·0 they will make the stars 0·5 mag. too faint, and below 12·0, 0·9 mag. too faint.

6. Next, taking the logarithms of the numbers in Table I. and treating them in the same way as Professor Turner has done in several papers (see *Monthly Notices*, lxxv. p. 63), that is, subtracting the mean of each column from each number in the column and then subtracting one column from the remainder, we form Table II. Since the column N_{30} has been taken as standard and subtracted from the remainder, this column is omitted, and the signs of the column headed N_{50} are changed so as to be comparable with the other columns.

TABLE II.

Values of log N' to log N'$_{30}$ for Selected Magnitudes in Units of 0·01.

R.A. h	N_{50}	N_{20}	N_{12}	N_8	Gal. Lat.
0	− 6	− 9	−16	−25	−77
1	− 9	− 7	−11	−16	−75
2	−13	− 1	− 1	−11	−64
3	0	+ 7	+ 4	− 6	−51
4	+14	+ 6	+ 6	+ 2	−38
5	+ 6	− 9	−19	−33	−24
6	+ 8	0	− 4	−14	−11
7	−11	+14	+20	+19	+ 1
8	− 6	+ 2	+ 6	+ 6	+14
9	+ 3	+ 6	+ 6	+ 7	+25
10	+ 1	+ 2	+ 7	+ 9	+35
11	+ 2	+ 6	+10	+17	+42
12	+ 5	− 2	+ 3	0	+45
13	+ 8	− 4	− 2	+ 2	+44
14	− 6	− 4	− 6	0	+39
15	+ 3	+ 4	+ 7	+12	+31
16	+10	− 8	− 9	− 2	+20
17	+10	− 4	0	+11	+ 8
18	− 3	− 1	+ 4	+21	− 4
19	+16	+20	+26	+41	−17
20	−11	0	+ 2	+ 4	−30
21	−10	−10	−15	−23	−43
22	+ 2	− 2	− 6	− 8	−57
23	−13	− 6	−12	−17	−69

Looking at the column headed N_8, it is at once evident why the lines have been drawn separating the region 7^h to 20^h from the rest. We have here a discontinuity similar to those found by Professor Turner in other zones. Following Professor Turner, I shall speak of the region 7^h to 20^h as unobscured, and of the region 21^h to 6^h as obscured, simply for convenience, without intending to imply that the difference is necessarily due to any actual obscuring matter in space. It may be noted that the obscured region from 21^h to 6^h fits very well into the diagram given by Professor Turner in *Monthly Notices*, lxxv. p. 480.

7. Now, taking the numbers given in Table I. and multiplying by such factors as to reduce the total number of stars in each hour of R.A. to about 2000, we can determine the amount of the obscuration without giving undue weight to the galactic regions. Without giving the details, we arrive at the results shown in Table III., where I., II. are the obscured and unobscured regions respectively. Table III. is similar in form to Tables V., VII., XIII., XIV. in *Monthly Notices*, lxxv. p. 470. In this case log N_{50} has been subtracted from the other logarithms.

TABLE III.

Amount of Obscuration, Zone − 17°. *Logarithms in Units of* 0·01.

Mag.	9·14.	10·77.	11·55.	12·25.	12·94.
I.	867	3788	3878	5645	5774
II.	742	2924	4020	7288	13318
log I.	0	64	65	82	83
log II.	0	60	73	99	125
log I.-II.	0	+4	−8	−17	−42

8. It will be seen that the final figure comes out −42 in exact agreement with the number found in other zones; and, comparing the amount of obscuration with the two adjacent zones as given in *Monthly Notices*, lxxv. p. 480, we get—

Mag.	10·0.	11·5.	13·0.
Algiers −1°	−10	−18	−42
Hyderabad −17°	0	−7	−42
Perth −32°	0	0	−42

So that the Hyderabad results fall naturally between the other two. In the Hyderabad zones the obscuration begins about 11·0.

9. Now, arranging the numbers of Table II. according to galactic latitude, we obtain the results shown in Table IV.

TABLE IV.

Amount of Galactic Condensation.

Obscured Region.						Unobscured Region.					
Mean Gal. Lat.	No. in Group.	9·14.	11·55.	12·25.	12·94.	Mean Gal. Lat.	No. in Group.	9·14.	11·55.	12·25.	12·34.
−71°	4	−10	−6	−10	−17	+41°	5	+2	0	+2	+6
−50°	3	−3	−2	−6	−12	±25°	5	+4	+4	+6	+12
−24°	3	+9	−1	−3	−15	±70°	4	−2	+3	+8	+14

10. Determining the coefficient of galactic condensation per magnitude per degree from the first and last rows only, and in each case taking the simple mean of the four determinations, we have the result—

Coefficient of galactic condensation.

Unobscured region −·00065. Obscured region −·00142.

The first result falls between those for Algiers and Perth, the second is slightly larger than either Algiers or Perth (see *Monthly Notices*, lxxv. p. 608). They do not lend support to the unusually high value in the case of the Cape Zone −41°. The mean value −·00104, however, lends some support to the suggestion that there is an increase in the amount of galactic condensation as we proceed southwards.

Nizamiah Observatory, Hyderabad:
1917 *January* 17.

Errata in the Double-Star Measures of the "Monthly Notices," Volumes LXVI. to LXXV. By Eric Doolittle.

In the course of copying all the double-star measures published in the *Monthly Notices* for the past ten years, the following errors have been detected. It is hoped that this list is an exhaustive one: perfectly obvious misprints, such as can cause no inconvenience, are, however, for brevity, not referred to.

Volume LXVI.

Royal Observatory, Greenwich.

Page 24. Ho 57, BC. Apparently this may be some other pair.

„ 26. Hu 482. Apparently the wrong star. The measures describe β 1115, and may belong to this.

„ „ Hu 483. Apparently the wrong star; (= See 277?).

Page 27. Ho 74. A large error in the angle. (For 30°·7 write 130°·7 ?)
„ 28. Σ 2349. The distance is about 6″ too small; (= 7″·28 ?).
„ „ Σ 2352. The measured distance is about 12″ too small.
„ 29. Ho 89. Misprint in distance. Probably should be 6″·43.
„ 503. For Ho 328 read Ho 238.
„ 507. Σ 2170. Misprint in angle; (= 70° ?).
„ 508. Σ 2341. This measure apparently belongs to Σ 2344.
„ „ Σ 2367. The measured distance is evidently in error.
„ „ Hu 676. The wrong star (?).
„ 509. Σ 2703. The measures belong to some other pair.
„ „ Σ 2726. Either misprints in angle and distance, or the wrong pair.
„ „ Σ 3113. The R.A. is 19 hrs. too great and the Decl. 16° too great.
„ 508. + 14° (3718). The Decl. is 1° in error.
„ 509. Σ 2802. The R.A. is 10 min. in error.
„ 510. For β 89 read β 989.

Espin, pages 141–144.

Holmes (17 hrs. 52·1 min.) is Σ 2246.
Hh 583. The companion is not new; measured by β in 1879.
For Sh 348 read Sh 358.

Volume LXVII.

Espin.

Page 190. H 5450. This is G.C. **58**, 52 sec. and 6′ away from H's place. The latter star was not found by β.
„ „ H 631. The R.A. is 1 hr. too great. These measures apparently belong to the neighbouring H 1065 = G.C. **558**.
„ 191. H 524. H and Scheiner reverse the quadrant.
„ „ H 587. The R.A. is 2 hrs. too small.
„ 191. H 263. The R.A. is 2 hrs. too small.
„ 192. H 1834. The star C was noticed by β in 1905, but not fully measured by him.

Volume LXVIII.

Royal Observatory, Greenwich.

Page 43. Ho 542. The first magnitude is 8·8, not 6·8.
„ 44. Lewis (15 hrs. 24 min.); this is Ku 50 = G.C. **7281**.

Page 527. Espin 278. This is identical with Σ 3114.
„ 530. Ho 442. The position and magnitudes are incorrect.
„ 532. The unidentified star at 20 hrs. 16 min. is apparently Ho 125.
„ 533. Ho 179. The R.A. is 4 min. too small.

Espin, page 203.

H 495. The R.A. is 2 hrs. too small.
H 1651. Error of 100° in angle (?).
H 1657. This pair is +47° (3462); it was measured by β in 1911. The pair measured by Espin is new.
H 1705. According to the description on page 204, the Decl. is here 12′ too great.

Volume LXIX.

Espin.

Page 219. H 2667. Identified by Espin with +48° (3136), but this is an error, for this star is in a different place. Espin's position nearly agrees with +49° (2236), and the pair may be this star.
„ „ H 1274. Identified by Espin with +42° (2604). If this is correct, the place given is 2 min. in error. No DM star in the position given.
„ „ H 1478 (1). This pair is H 1472. Measured by β and Doolittle.
„ „ H 1478 (2). From Espin's position this pair seems to be 25 sec. following and 5′ N of H 1478. The latter pair was measured by me on three nights in 1907.
„ 222. β —. For G.C. **994** read G.C. **944**.

Royal Observatory, Greenwich.

Page 594. β 928. The R.A. is 20 min. too small.
„ 596. For AG 167 read AG 197.
„ 597. Ku 43. The position given is that of Ku 53, but the measure does not describe either pair. I have no record of any pair in Lewis's position answering to his description.
„ „ OΣ 310. This measure apparently belongs to the neighbouring pair, Ho 405.
„ „ Weisse 31. This measure apparently belongs to some other pair.
" 600. Aitken 368. The measures belong to this pair, but the position given is that of OΣ 368.

Volume LXX.

Espin, page 239.

Kustner 23 should be Krueger 23.
For Hussey 394 read 794.

Royal Observatory, Greenwich.

Page 636. Σ 3072. There is an error in the distance, or this is the wrong pair.
„ 646. AG 219. An error in distance, or some other pair.

Volume LXXI.

Phillips, page 216.

Σ 401. The R.A. is 1 hr. too great.
Σ 427. The R.A. is 10 min. too small.

Espin, page 218.

H 2428. The R.A. is 1 hr. too small.
+48° (1900). The Decl. is 40′ too small.
+51° (2487). If this identification is correct the R.A. is 1 hr. too small and the Decl. is 20′ too large. No DM star in Espin's place.

Royal Observatory, Greenwich.

Page 734. AG 122. The measures evidently belong to Aitken 122. The position stated and the magnitudes are incorrect.
„ 735. Σ 1114. Angle 200° too large, probably from a misprint.
„ 737. Perrotin. There is evidently an error of about 100° in the angle.
„ 739. OΣ 276. Evidently an error in the printed distance of AC.
„ 740. Σ 1912. The distance is in error.
„ „ Ku 50. The distance is in error.
„ 741. Hu 748. An error in the distance (?).
„ 743. Σ 2165. The angle about 200° in error.
„ „ β 130. The R.A. is in error.
„ 745. OΣ 362. The measures belong to some other star.
„ „ Lewis (19 hrs. 4 min.). No position given; meaning of angle printed is uncertain.
„ 749. Ho 480. Entered twice, the second time with an erroneous R.A.
„ „ Σ 2900. Apparently the measures belong to Σ 2990. The R.A. and Decl. are incorrect.

Volume LXXII.

Jonckheere, page 157.

J. 43. Both angle and distance disagree with the values published in *J.A.*, i. p. 151.

Espin, page 192.

+49° (3131). Evidently either this measure or the one published in *M.N.*, lxix. p. 221, is in error.
+49° (3216). The Decl. is 9′ too large.

Volume LXXIII.

Royal Observatory, Greenwich.

Page 95. β 1315 and Hu 1044. These pairs are identical.
„ 101. Aitken 224. The measures belong to some other pair (β 339?).
„ 102. H 570 should be Hussey 570.
„ „ 1324. This is β 1324.
„ „ 1672. This is Σ 1672.
„ 103. AG 192. An error in distance, or some other pair.
„ 105. Hu 661. Evidently an error in the angle.
„ 106. Lewis 14. Evidently a large error in this distance, or else in that of 1900 (*M.N.*, lxxi. p. 486).
„ 113. AG 267. There is an error in the distance.

Phillips.

Page 159. Σ 87. The R.A. is 10 min. in error.
„ 161. H 1317. These measures belong to a faint pair first noticed by Miller in 1904. The H pair is 31 sec. following and 20′ S. (See *Pub. Flower Observatory*, iv.)

Volume LXXIV.

Royal Observatory, Greenwich.

Page 139. Σ 930 should be Σ 950.
„ 141. β 858 should be β 585. The magnitudes are in error.
„ „ Aitken. This is A 2131; it forms the principal star of Ho 357.
„ 142. Σ 3121. The angle is evidently in error.
„ „ Σ 1372. The second measure belongs to some other star; possibly to Ho 369, which is 13 min. following.
„ 143. Σ 1634. There is evidently a large error in the distance.

Page 144. Σ 1700. Evidently an error in distance.
,, 145. Σ 1834. Error in angle (= 91°·1 ?).
,, 152. OΣ 382. A large error in angle, or some other pair.

Espin.

Page 244. +46° (1476) should be +45° (1476).
,, ,, Aitken 1774 should be A 1744.
,, 246. Σ 2658. *a* was also measured by Espin in 1910.
,, ,, H 1635. The angle differs 100° and the distance 4″·2 from the measure of Espin in 1909. Misprints, or some other star.
,, ,, +49° (4189). The description in exact agreement with that of +49° (4188), which was measured by Espin in 1909, but the latter pair is 11′ N. The two pairs identical (?).

Phillips and Acocks, pages 443–444.

Σ 2264. For 359°·0 read 259°·0 (?).
Σ 2279. The printed distance incomplete.
Σ 3008. Misprint in angle; probably should be 228°·3 or 238°·3.

Franks.

Page 531. σ 434. For 10° 50′ read −10° 50′.
,, 534. H 5524. This is either a more distant companion, not noticed before, or else some other pair.

Volume LXXV.

Franks, page 101.

Σ II, 9. The distance is incompletely printed.

Voûte.

Page 432. Σ 517. The measures belong to some other pair.
,, 433. I 15·72, Howe 37. This is apparently not I 15·72, nor does it answer the description of Howe 37. It is just possible that the pair is Σ 3095, with slight errors in the angle and distance.

The Flower Observatory,
University of Pennsylvania:
1916 *November* 1.

Preliminary Values of the Variation of Latitude at Greenwich for 1916.

(*Communicated by the Astronomer Royal.*)

The results given in this paper have been derived from measurements of 216 plates taken with the Cookson Floating Zenith Telescope.

The paper is a continuation of the preliminary discussion by Mr. Jones which appeared in the *Monthly Notices* for 1915 May, and the data for star places and proper motions are those found and used in that paper.

The aberration has been assumed to be 20″·47. No corrections have been applied for stellar parallax.

The minimum number of plates obtained in a section (tenth part) of the year was 8, and the maximum number 29.

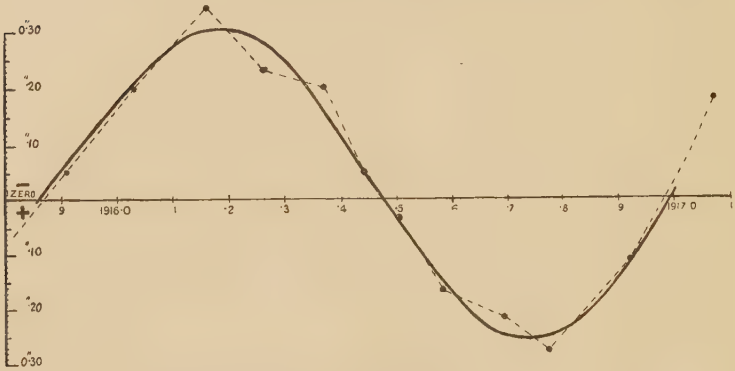
The probable error of a result from one plate is taken as ±″·056 (*M.N.*, vol. lxxv. p. 544), and from this the result in the last column of the table is derived.

Variation of Latitude at Greenwich in 1916.

Section.	Epoch.	Variation.	Prob. Error.
		″	″
44	1916·03	−·201	±·013
45	·16	−·347	·020
46	·26	−·234	·011
47	·37	−·202	·011
48	·42	−·052	·014
49	·50	+·032	·014
50	·58	+·165	·010
51	·69	+·218	·014
52	·77	+·279	·011
53	·92	+·110	·014
54	1917·08	−·179	·015

A table of corrections for latitude variation on selected dates applicable to observed N.P.D.'s is appended.

These corrections were read from a smooth curve drawn through the above results plotted as points on squared paper.



Latitude Variation at Greenwich during 1916.

Table of Corrections applicable to observed N.P.D. for Variation of Latitude.
(Longitude of Greenwich.)

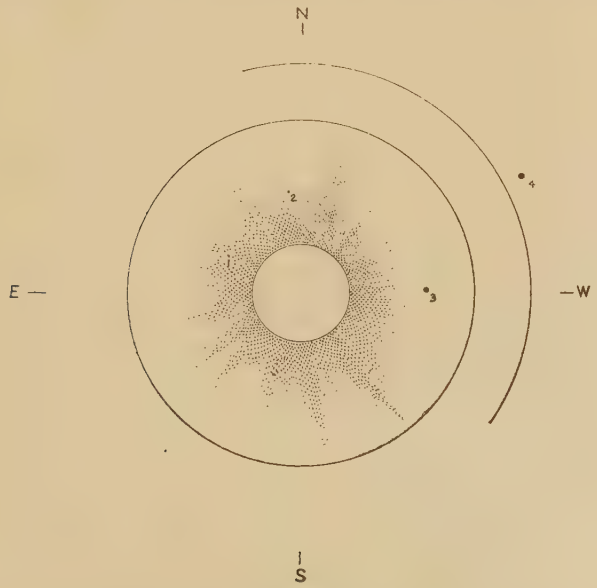
Date.	Corrn.	Date.	Corrn.
	"		"
1916 Jan. 1	+0·18	1916 July 1	−0·03
11	·21	11	·07
21	·23	21	·11
Feb. 1	·26	Aug. 1	·15
11	·28	11	·18
21	·30	21	·21
Mar. 1	·30	Sept. 1	·23
11	·31	11	·24
21	·30	21	·25
Apr. 1	·29	Oct. 1	·25
11	·27	11	·24
21	·24	21	·23
May 1	·21	Nov. 1	·21
11	·18	11	·18
21	·14	21	·15
June 1	·09	Dec. 1	·12
11	·05	11	·08
21	+0·01	21	−0·04
July 1	−0·03	31	0·00

On the Opportunity afforded by the Eclipse of 1919 *May* 29 *of verifying Einstein's Theory of Gravitation.* By Sir F. W. Dyson, M.A., LL.D., F.R.S.

According to Einstein's theory, a ray of light passing near the Sun will be deflected by an amount $1''{\cdot}75\,\frac{r_0}{r}$ where r_0 is the radius of the Sun and r the perpendicular distance of the ray from the Sun's centre. An examination was made of four photographs taken by Mr. Davidson with the astrographic equatorial at the eclipse of 1905. The brightest stars near the Sun at the time were :—

No.	Name.	Photog. Mag.	Dist. from Sun's Centre.	Displacement.
		m	′	″
1	Mayer 470	7·2	29	0·96
2	Lal. 20558	8·4	35	0·79
3	49 Leonis	5·7	43	0·64
4	ρ Leonis	3·9	86	0·32

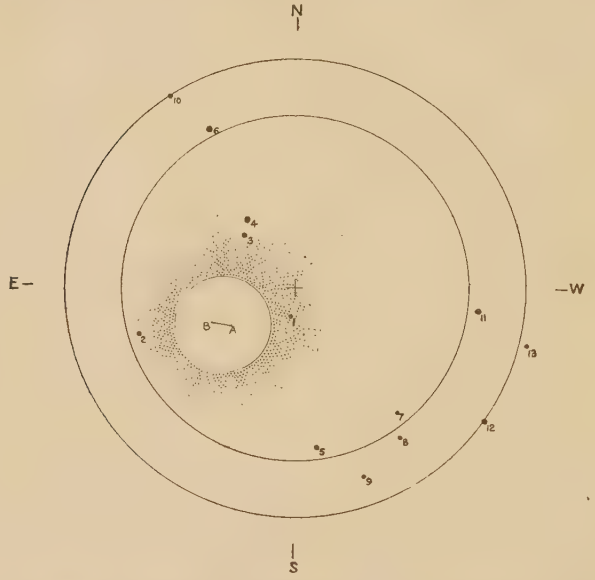
Their positions with a rough sketch of the corona are shown on the accompanying diagram. The two stars ρ Leonis and 49



Leonis were easily shown. It was thought that Mayer 470 was faintly visible. Accordingly, a key-plate was taken with the astrographic equatorial, and was placed film to film with the eclipse photographs in turn (these had been reversed owing to the employment of a cœlostat mirror at the eclipse), and the plates were carefully measured differentially and reduced. It was disappointing to find that the results were not sufficiently accordant

to serve as a verification, or the contrary, of Einstein's theory. It is probable that if the plates had been treated differently the star Mayer 470 would have been shown, but they were developed so as to give pictures of the corona. They show, however, that astrographic object-glasses are very suitable for this important observation, and the purpose of this note is to draw attention to the unique opportunities afforded by the eclipse of 1919 May 29.

The field of stars is shown in the accompanying diagram. There



are an unusual number of bright stars, and with weather conditions as good as those at Sfax in 1905—which were by no means perfect—no less than thirteen stars might be obtained. These are—

No.	Name.	Photog. Mag.	Dist. from Sun's Centre.	Displacement.
		m	′	″
1	B.D. 21° 641	7·0	23	1·20
2	Piazzi IV. 82	5·8	29	0·95
3	κ^2 Tauri	5·5	32	0·86
4	κ^1 Tauri	4·5	37	0·75
5	Piazzi IV. 61	6·0	55	0·50
6	υ Tauri	4·5	69	0·40
7	B.D. 20° 741	7·0	69	0·40
8	B.D. 20° 740	7·0	71	0·39
9	Piazzi IV. 53	7·0	71	0·39
10	72 Tauri	5·5	82	0·33
11	56 Tauri	5·5	88	0·31
12	53 Tauri	5·5	96	0·29
13	51 Tauri	6·0	105	0·26

This should serve for an ample verification, or the contrary, of Einstein's theory. Unfortunately, the track of the eclipse is across the Atlantic and near the Equator. Mr. Hinks has kindly undertaken to obtain for the Society information of the stations which may be occupied. I have brought the matter forward so that arrangements for observing at as many stations as possible may be made at the earliest possible moment.

Royal Observatory, Greenwich:
March 2.

Two Applications of Jacobi's Integral.

By Harold Jeffreys, M.A., M.Sc.

1. *Note on the Moulton-Gyldèn Theory of the Counterglow.*

Suppose that a planet of mass μ is moving in a circular orbit about the sun; if a very small body is free to move about the two together, then it is known that the only first integral of its equations of motion is the Jacobi integral, namely, in Moulton's notation *

$$\nu \equiv x^2 + y^2 + \frac{2(1-\mu)}{r_1} + \frac{2\mu}{r_2} - x'^2 - y'^2 - z'^2 = \text{const.}$$

Further, if fixed axes OX, OY, OZ be taken, coinciding with the moving axes when $t = 0$, we have

$$x^2 + y^2 = X^2 + Y^2;\ x'^2 + y'^2 + z'^2 = (X' + Y)^2 + (Y' - X)^2 + Z'^2.$$

Thus the integral can be expressed in terms of the co-ordinates and velocities referred to fixed axes without introducing the time explicitly. It follows at once by Jeans's theorem † that a system of such particles can be in a steady state if, and only if, the number of particles whose co-ordinates and velocity-components lie in the element $dXdYdZdX'dY'dZ'$ is $\chi(\nu)dXdYdZdX'dY'dZ'$, where χ is any function. It is easily proved that $\partial(XYZX'Y'Z')/\partial(xyzx'y'z') = 1$, and hence at any point the numerical density ρ is $\iiint \chi(\nu)dx'dy'dz'$.

Now, $x^2 + y^2 + \frac{2(1-\mu)}{r_1} + \frac{2\mu}{r_2} = 2U$ in Moulton's notation; the surfaces obtained by giving different values to U are the "surfaces of zero velocity." Put then $x' = \xi U^{\frac{1}{2}}$; $y' = \eta U^{\frac{1}{2}}$; $z' = \zeta U^{\frac{1}{2}}$.

Then $\rho = \iiint \chi\{U(2 - \xi^2 - \eta^2 - \zeta^2)\}d\xi d\eta d\zeta$, the limits being $-\infty$ to $+\infty$ in all cases. Hence ρ is a function of U only.

According to the theory of Gyldèn and Moulton, ‡ the counterglow is caused by light reflected from particles moving in the neighbourhood of the straight-line position of Lagrange's third particle. For these U must lie between two slightly different values, both

* *Celestial Mechanics*, 1914, p. 281.
† *Monthly Notices*, vol. lxxvi., 1915, p. 78.
‡ *Bulletin Astronomique*, t. 1; *Astronomical Journal*, No. 483.

being near that corresponding to the surface of zero velocity that has a double point.

The luminosity of the sky as seen from the earth is proportional to $\int \rho dr_2/r_1^2$, and as r_1 does not vary widely, it is nearly proportional to the depth (along a line through the earth) between two neighbouring surfaces of the system. It can be shown that this depth is greatest in the direction through the double point, so that the part of the sky just opposite to the sun is the brightest. An independent proof of the discovery of Gyldèn and Moulton is thus obtained.

2. *Orbital Motion in a Resisting Medium.*

It can be seen at once from the above that the mean value of each of x', y', and z' among the particles at any point is zero; in other words, however much the velocities may vary among themselves, the condition of steady motion requires the *average* velocity at any point to be the same as if the whole system was rotating like a rigid body.

Now, let x, y, z be the co-ordinates of a third body, large compared with the particles considered, but small compared with S and J. Then its equations of motion are

$$x'' - 2y' = \frac{\partial U}{\partial x} - \kappa x',$$

$$y'' + 2x' = \frac{\partial U}{\partial y} - \kappa y',$$

$$z'' \qquad = \frac{\partial U}{\partial z} - \kappa z',$$

where κ is a small quantity, depending only on U.

Multiply by x', y', z' respectively, and add. Then

$$\frac{d}{dt}(x'^2 + y'^2 + z'^2 - 2U) = -2\kappa(x'^2 + y'^2 + z'^2).$$

If the quantity C be *defined* now as equal to $2U - x'^2 - y'^2 - z'^2$, so that in the case of motion without a resisting medium it is the Jacobi constant, then it follows that resistance causes C to increase steadily, as has been stated by See. Thus the space that the third body is confined to will steadily diminish till it is ultimately forced to move either as an interior planet or a satellite of J. Lagrange's particles, corresponding to a minimum point of U, will be secularly unstable. As the general motion of the medium is direct, retrograde satellites will experience more resistance than direct ones, and therefore approach their primaries more rapidly. If then we can grant that the attraction of the other planets produces no important effect on the secular changes in the orbits, the fact that the known retrograde satellites are all on the outside of their systems renders it very unlikely that they have been captured by the action of a medium in a state of steady motion.

The Viscosity of the Earth. (Third Paper.)

By Harold Jeffreys, M.A., M.Sc.

In a former paper with a similar title to the present* I showed that if the materials of the earth be assumed to obey the "elastico-viscous" law used by Sir G. H. Darwin, and the degree of viscosity were chosen to make the lunar secular acceleration due to tidal friction agree with the observed value, then the Eulerian nutation would die down in a few days. The observed fourteen-monthly variation of latitude could not then be a free vibration. This appeared improbable, and several alternative explanations were offered; one was that the elastico-viscous law was perhaps widely different from the truth. This now appears to be the most plausible of them. The object of the present paper is to indicate the consequences of a new type of solid viscosity, which is here termed "firmo-viscosity," and which enables the formerly apparently conflicting facts to be reconciled.

The Viscosity of Solids.

The existence of some kind of dissipation of energy in the interior of a solid body when a stress is applied is generally recognised, but hitherto little work seems to have been done on the precise laws that govern this dissipation. The law known as that of "elastico-viscosity" was used by Sir G. H. Darwin in his work on tidal friction; the equations of motion of a solid obeying it were first given by Mr. J. G. Butcher, but the original idea appears to have been due to Maxwell.† If a perfectly elastic body be suddenly strained, and inertia can be neglected, then the strain immediately attains the value given by the equation

$$n\mathrm{S} = \mathrm{F} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where S is the strain and F the stress, and n is a constant proportional to the coefficient of rigidity. No further change takes place till the stress is removed, when the strain at once sinks to zero. If the body be elastico-viscous, however, the stress-strain equation is most conveniently expressed in the form

$$n\mathrm{S} = \dot{\mathrm{F}} + \frac{1}{\mathrm{t}_1}\int \mathrm{F}\,dt \quad . \quad . \quad . \quad . \quad (2)$$

where t_1 is a constant. In this case a sudden stress gives an immediate strain F/n as before, but the solid then proceeds to flow at a uniform rate $\mathrm{F}/n\mathrm{t}_1$ till the stress is removed; the strain then does not sink to zero, but to $\mathrm{FT}/n\mathrm{t}_1$, where T is the time for which the stress acted. A permanent set is therefore possible if this law holds.

An alternative law was suggested to me by Sir Joseph Larmor

* *Monthly Notices*, vol. lxxv., 1915, p. 648.
† *Phil. Mag.*, vol. xxxv., 1868, p. 134.

some time after the publication of my former paper. According to this, the stress-strain equation is

$$n\left(\mathrm{S}+\mathrm{t}_2\frac{d\mathrm{S}}{dt}\right)=\mathrm{F} \quad . \quad . \quad . \quad . \quad (3)$$

There is a frictional term proportional to the rate of straining, which appears decidedly probable. When a constant stress is applied the strain approaches asymptotically the value F/n, and when it is removed the strain returns asymptotically to zero. Permanent set is therefore absent; this kind of viscosity does not imply weakness, but an additional stiffness. For this reason it will henceforth be referred to as "firmo-viscosity." The two types of internal resistance may be combined in the single formula

$$n\left(\mathrm{S}+\mathrm{t}_2\frac{d\mathrm{S}}{dt}\right)=\mathrm{F}+\frac{1}{\mathrm{t}_1}\int \mathrm{F}dt \quad . \quad . \quad . \quad (4)$$

The strain tends to approach asymptotically to the value $\frac{1}{n}\left(\mathrm{F}+\frac{1}{\mathrm{t}_1}\int \mathrm{F}dt\right)$, which on account of permanent set increases steadily. When the stress is removed the strain sinks asymptotically to the constant value $\mathrm{FT}/n\mathrm{t}_1$. The observations of Trouton and Andrews on substances like pitch, wax, and glass * in a plastic condition appear to agree very well with this law.

If in this we put $\mathrm{t}_1=\infty$, the viscosity follows Larmor's law, while if $\mathrm{t}_2=0$ it follows Maxwell's. If t_1 is not infinite, it is evident that the body cannot remain in equilibrium unless there are no deforming forces acting, *i.e.* unless it is in a hydrostatic state. If, on the other hand, $\mathrm{t}_1=\infty$, permanent equilibrium is possible when constant deforming forces act. This evidently corresponds with the condition of materials used in building, such as girders and struts.

It appears that it will be impossible to frame a plausible law of viscosity that will permit an unlimited flow when a stress is indefinitely prolonged, without permanent set occurring; the converse is also true. For, first suppose a permanent set to remain after a stress has been applied and removed. Then F and all its derivatives are zero; the only difference between the actual body and one that has never been strained is that in the actual case $\int \mathrm{F}dt$ is not zero. Hence permanent set implies the presence of this integral in the stress-strain relation. But this integral increases steadily with the time when the force is uniform, and the strain must therefore also increase indefinitely. Conversely, if the strain increase indefinitely when a uniform stress is applied, the strain must depend on $\int \mathrm{F}dt$, and hence a permanent set will remain when the stress is removed. Indefinite flow under constant stress and permanent set are thus completely associated.

* *Phil. Mag.*, ser. vi., vol. vii., 1904, p. 347.

If a problem has been solved for the case of perfect elasticity ($\mathfrak{t}_1=\infty$, $\mathfrak{t}_2=0$), the rigidity being n, the solution of the general case can be obtained from this by replacing n by the operator

$$c=n\left(1+\mathfrak{t}_2\frac{d}{dt}\right)\Big/\left(1+\frac{1}{\mathfrak{t}_1\frac{d}{dt}}\right).$$

In the previous paper $\mathfrak{t}_2$ was assumed to be zero. It was found that the lunar secular acceleration made $\mathfrak{t}_1=1$ day nearly, so that for movements with a fourteen-monthly period $\mathfrak{t}_1 d/dt$ and therefore c were exceedingly small. The earth would therefore behave like a perfect fluid ($n=0$), and a Eulerian nutation would be impossible. With any value of $\mathfrak{t}_1$ of the order of a day, and any value of $\mathfrak{t}_2$ less than a year, this would still hold. We may safely say, then, that the accepted theories of tidal friction and the variation of latitude cannot be reconciled if Maxwell viscosity is important. Hence $\mathfrak{t}_1$ must be practically infinite; in other words, there is no permanent set in the earth for small stresses.

A confirmation of this may be found in the imperfection of isostasy. Uncompensated surface inequalities exist which must cause a considerable shearing stress even at a depth of thousands of kilometres; yet they are supported, which could not happen if the interior of the earth showed any permanent set for small strains.

Next, we may consider the case of firmo-viscosity. Now

$$c=n(1+\mathfrak{t}d/dt).$$

The suffix may be dropped without ambiguity.

For a homogeneous earth, let E denote the amplitude of the actual semidiurnal bodily tide divided by that of the equilibrium tide, and ϵ its lag. Then in the notation of the previous paper

$$\mathrm{E}e^{-i\epsilon}=\left\{\frac{19n}{2g\rho a}(1+ip\mathfrak{t})+1\right\}^{-1}.$$

E is about 0·70, and the secular acceleration of the moon requires ϵ to be about 1° 5′. We find then

$$\tan^{-1}\cdot 7p\mathfrak{t}=1^\circ\ 5',\ \text{whence}\ \mathfrak{t}=6^{\mathrm{m}}\ 11^{\mathrm{s}}.$$

If $1/\tau_0$ be the ellipticity of the Maclaurin ellipsoid rotating in 24^{h}, then the pitch of the Eulerian nutation is given, in the notation of the complex variable, by the equation

$$\frac{86400\tau_0 p}{2\pi}=\frac{7(1+ip\mathfrak{t})}{7(1+ip\mathfrak{t})+3},$$

the unit of time being 1 second.

Putting $\tau_0=232$, we find that one root of this makes

$$p=(1\cdot 89\times 10^{-2}+4\cdot 6\times 10^{-7}i)/1\ \text{day}.$$

The motion of the pole is then a circular one of period 331 days, with an amplitude proportional to $e^{-4\cdot6\times10^{-7}t}$. The amplitude thus dies down very slowly, the life of the vibration being of the order of 10,000 years. The Eulerian nutation can therefore persist on this hypothesis.

The other root makes $p=\frac{26\iota}{1 \text{ second}}+\frac{2\pi}{232 \text{ days}}$.

The amplitude of this vibration thus declines to zero in a few minutes. Its physical meaning is, that if the earth were originally rotating about its axis of symmetry, and the axis of rotation were suddenly displaced without being given any transverse motion, it would rapidly return to rest along the axis of symmetry on account of viscosity. The neglect of inertia in calculating the elastic strain produced is probably not justified for this motion, but the order of magnitude of the importance of viscosity is unlikely to be wrong, and in any case such a movement is obviously of little astronomical interest.

The theories of tidal friction as an explanation of the secular acceleration of the moon's mean motion and of the Eulerian nutation as an explanation of the fourteen-monthly variation of latitude can therefore be reconciled if the viscous parts of the earth are supposed to obey Larmor's law instead of Maxwell's.

The former Viscosity of the Earth.

If we accept the hypothesis that the earth was formerly gaseous, it follows at once that at some date it was liquid. If, on the other hand, the Planetesimal Hypothesis were true, it is somewhat uncertain whether the earth could have been liquid or not. The velocities with which the planetesimals struck the earth must have been of the same order of magnitude as planetary velocities, and therefore great enough to cause fusion if the heat were retained; if the accretion were very slow, however, heat might be radiated away sufficiently fast to prevent fusion. Even on the hypothesis designed to render unnecessary the hypothesis of a molten earth, it is then very doubtful whether the earth could always have been solid. It will here be assumed that it was once liquid.

If the first section of this paper be considered to have established that the Maxwell coefficient of viscosity is infinite, the physical arguments that I have elsewhere based * on its continuous increase from a very small amount to a very large one, through the value that would make tidal evolution proceed at its maximum rate, will still hold in their entirety. On the hypothesis of a formerly molten earth, then, Darwin's theory of tidal friction as an important factor in the past history of the earth and moon seems necessarily true. When the changes were taking place most rapidly elastico-viscosity must have been much more important

* *Phil. Mag.*, vol. xxxii., 1916, p. 590; or *Monthly Notices*, vol. lxxvi., 1915, p. 85.

than firmo-viscosity. A certain amount of information may yet be obtained from the theory of firmo-viscosity alone.

The secular retardation of the earth's rotation was found by Darwin * to be $1900^{s}\ E \sin 2\epsilon$ "in a century," the semidiurnal tide alone being considered. But the moon's secular acceleration in a century is $413''\ E \sin 2\epsilon$,† and is observed to be $4''{\cdot}5$. It follows that if v be the earth's angular velocity,

$$\frac{dv}{dt} = -621'' \div (1 \text{ century})^2.$$

Now the estimates of the age of rocks from the ratio of uranium to lead in them have led to the conclusion ‡ that since the oldest known rocks became solid not less than $1{\cdot}6 \times 10^9$ years have elapsed. The change in v in this time is found to be 75·9 degrees per day. This estimate is, however, only a minimum, for during part of the time elastico-viscosity would probably be important, and the rate of change would consequently be more rapid. Further, the moon's tide-raising power is supposed to have been constant, whereas it must have decreased on account of the increasing separation of the two bodies. For both reasons we conclude that at the commencement of the period considered the earth's angular velocity was greater than 360 + 75·9, or 435·9 degrees per day. Hence the period of rotation was less than 0·827 days. The ellipticity of the earth's surface corresponding to such a period would be about $\frac{1}{202}$. Yet at the present time the strata of equal density within the earth have, to a considerable degree of accuracy, the hydrostatic ellipticity throughout. In accordance with previous results,§ then, the earth must since have adjusted itself to the hydrostatic form in consequence of some weakness in its structure. This adjustment would cause compression at the equator and tension at the poles; if it took place suddenly, a series of mountain chains with a north and south trend would have been produced round the equator. It seems more probable that the adjustment occurred in a series of small stages, as no relics of the large mountains required by sudden adjustment can now be traced. A series of small adjustments at long intervals would probably be more easily hidden by denudation and crust-movement than a single very large one. Continuous adjustment is not impossible, as it would only require a very slow permanent set for small strains; t_1 might be many thousands of years without making the process too slow, and the hypothesis of the first section that it is infinite would remain sufficiently accurate. The whole change of ellipticity here considered would yet be insufficient to cause set or fracture in the materials of the earth under the conditions prevailing at the surface. Small adjustments, therefore, imply that the materials

* *Sci. Papers*, vol. ii. p. 68.
† *Ibid.*, p. 73.
‡ Holmes, *Geol. Mag.*, decade vi., vol. ii., 1915, p. 108.
§ *Memoirs R.A.S.*, vol. lx., 1915, p. 197.

of the interior of the earth are much weaker than those of the crust; Barrell's theory * of a layer of solid but weak matter below the crust agrees with this, and it would not be surprising if the weakness extended to the centre of the earth, especially as the centre of the earth is the point that has cooled least since solidification, and hence may be expected to be the place of easiest fusion.

Application to the Theory of Earthquake Waves.

In a transverse earthquake wave it is well known that the displacement at any point can be derived † from the complex function $\frac{1}{r}\exp \iota\kappa\,(\mathrm{V}t - r)$, where r is the distance from the focus, V the velocity of transmission, and $2\pi/\kappa$ the wave-length. We have then

$$\mathrm{V}^2 = \frac{c}{\rho} = \frac{n}{\rho}(1 + \iota p\mathfrak{t})$$

in the present notation, ρ being the density of the rock.

Hence, if $p\mathfrak{t}$ is small,

$$\mathrm{V} = \mathrm{V}_0(1 + \tfrac{1}{2}\iota p\mathfrak{t}), \text{ where } \left(\frac{n}{\rho}\right)^{\frac{1}{2}} = \mathrm{V}_0.$$

Then the displacement is proportional to

$$\frac{1}{r}\exp \iota\kappa\left\{\left(1 + \frac{\iota p\mathfrak{t}}{2}\right)\mathrm{V}_0 t - r\right\}$$

$$= \frac{1}{r}\exp\left(-\mathrm{V}_0\frac{p\kappa\mathfrak{t}t}{2}\right)\exp \iota\kappa(\mathrm{V}_0 t - r).$$

A damping factor is thus introduced, and becomes important after a time $2/p\kappa\mathfrak{t}\mathrm{V}_0$. But $p = \kappa\mathrm{V}_0$, and therefore the time needed is $2/p^2\mathfrak{t}$. In this time the wave has travelled a distance $2\mathrm{V}_0/p^2\mathfrak{t}$, and thus the slowest vibrations get furthest from their source. The period of earthquake waves is usually of the order of 20 seconds. ‡ V_0 is about 4×10^5 cms. per second at the surface, and probably not much more than 6×10^5 cms. per second at the centre of the earth. If then $\mathfrak{t}$ were as small as one second, transverse earthquake waves could not penetrate to more than about 100 kilometres from their source. The actual value of $\mathfrak{t}$, already obtained as a statistical weighted average for the whole earth, is 371 seconds, so that the existence of these waves is conclusive evidence against the uniform distribution of so high a degree of viscosity. The viscosity may, however, be concentrated into a small bulk, possibly very near the centre of the earth, without preventing the transmission of earthquake waves.

* *Journal of Geology*, 1914–15.
† Love, *Theory of Elasticity*, 1906, p. 282.
‡ G. W. Walker, *Modern Seismology*, p. 51.

Need for Further Inquiry.

The evidence here obtained from the fourteen-monthly variation of latitude and from earthquake waves appears to leave little room for imperfection of elasticity within the earth except in a small region, and bodily tidal friction can occur only inside this small region, if at all. At present the sole evidence of imperfection of elasticity is that afforded by the secular accelerations of the sun and moon, and the apparent trustworthiness of this is somewhat diminished by the fact that these are not in the theoretical ratio.* The unduly large secular acceleration of the sun then requires explanation if the datum given by the moon is accepted. It is possible that when the theory of earthquake waves has been considerably improved the behaviour of these may give further information about the viscosity near the centre of the earth. Several attempts have been made to measure the lag of the bodily tides directly by means of the horizontal pendulum;† but although this would give valuable information if it could be accomplished, success seems very unlikely. If the ocean were absent the problem might be soluble, but the tides in it lag to a tremendous extent quite independently of viscosity, the lag being in some places positive and in others negative, and due entirely to the irregular forms of the bed and the coast.‡ The attraction of these tides and their pressure on the ocean bottom deform the solid earth to an extent comparable with the bodily tide and inseparable from it,§ and must transmit to the solid earth their lags, thus causing retardations in some places and accelerations in others so much greater than the true lag of the bodily tide that to separate the latter from them will be practically impossible. As the secular acceleration cannot be produced except by a dissipative force, and these oceanic lags are not caused by viscosity, it follows that the sum of their effects (direct and indirect) on the moon must necessarily be zero. When only a finite number of observing stations is available, however, they are sufficient to mask the true effects of viscosity completely. Oceanic viscosity itself would produce in an ocean of uniform depth‖ a lag of $0^{s}\cdot001$, which would be quite imperceptible, and the order of magnitude of the dissipation of energy in the sea, and hence its contribution to secular accelerations, is not likely to be changed by the irregular form of the bed.

More information on the present secular accelerations is particularly desirable on account of its bearing on the past history of the earth. It has already been shown that the value of the

* J. K. Fotheringham, *Monthly Notices*, vol. lxxv., 1915, p. 396; *Monthly Notices*, vol. lxxvi., 1915, p. 85.

† Michelson, *Astrophysical Journal*, vol. xxxix., 1914, p. 122.

‡ H. Lamb and L. M. Swain, *Phil. Mag.*, June 1915; Goldsbrough, *Proc. Lond. Math. Soc.*, vol. xv., 1916, p. 64.

§ K. Terazawa, *Phil. Trans.*, vol. ccxvii. *a*, 1916, pp. 35–50.

‖ *Monthly Notices*, vol. lxxv., 1915, p. 658.

secular acceleration of the moon generally accepted implies frequent adjustments of the earth to the hydrostatic form during geological time. This would not be necessary if tidal friction did not at present exist; the moon might have attained its present orbit before the earliest known sedimentary rocks were formed.

Summary.

The existence of the Eulerian nutation and the transmission of transverse earthquake waves together imply that nearly the whole of the earth may be regarded as perfectly elastic except for forces with periods of a century or more. If bodily tidal friction be regarded as the cause of the secular acceleration of the moon's mean motion, it must be confined to a comparatively small firmo-viscous bulk, probably near the centre of the earth. Elastico-viscosity can nowhere be important at present, although it must have been a very important factor in controlling the past history of the system. The time it takes to cause permanent set for small strains must be many years. On the basis of the observed secular acceleration of the moon, it has been shown to be most likely that the earth adjusted itself to the hydrostatic state during geological time by a series of small steps.

Occultation of B.D. $+21^\circ$ 1714, *by Saturn's Ring*, 1917 *Feb.* 9.

By Naval-Instructor M. A. Ainslie, R.N., B.A.

1917 Feb. 9, at about $8^h\ 45^m$ G.M.T., I noticed a star of about the 7th magnitude north of, and preceding, the N. pole of Saturn. It was of a golden-yellow colour.

Circumstances prevented further observation until after 10 p.m., when the planet was again observed, but in poor seeing.

It was not until about 10.15 that the star was again seen, when it appeared as a very conspicuous cream-white spot, very small, and apparently projected on the extreme edge of ring B; it passed into the division and travelled along it, remaining very conspicuous and, as nearly as I could judge, as bright as when clear of the planet. It does not appear to have passed behind any portion of ring B, as its brightness was so little affected; the appearance of its being projected on the ring was probably an effect of irradiation, the B ring being at its outer edge very bright.

At about 10.30 it was seen on the outer edge of the division, and (owing to bad seeing) disappeared for a few minutes; at about $10^h\ 35^m$, however, it was very easily seen, though greatly reduced in brightness, through ring A.

It remained visible to the end of the observation, and traversed

the ring with little or no variation in brightness, though at $11^h\ 8^m$ it increased very rapidly, not quite instantaneously, to perhaps double intensity, at which it remained for from 10 to 15 seconds, fading again as rapidly as it had brightened. A second brightening was observed at $11^h\ 8^m$, this time for not more than about 5 seconds.

The star finally appeared from behind ring A at $11^h\ 10^m$, and was seen separated from the ring by a distinct black interval at $11^h\ 15^m$.

During the passage of the ring over the star, and when seen through the Cassini division, the yellow colour of the star was much less pronounced than when clear of the planet before and after the observation; it was more in the nature of a creamy white. The image throughout was very "stellar," especially when seen through the Cassini division; there may have been a very slight enlargement of the image when seen through the ring. I should estimate that the star lost perhaps three-quarters of its light when seen through the ring, but any estimate of the brightness of the star was difficult on account of the glare of the planet. During the brief "brightenings" in ring A, the star did not attain to anything like its normal brilliancy.

The seeing was poor at first, but improved considerably; for a few minutes at about $10^h\ 20^m$, and again from about $10^h\ 35^m$ to $11^h\ 15^m$, the seeing was good, and the image of the star small and round.

A 9-inch silvered reflector was used in the observation, powers 180 and 270.

The alteration in brightness of the star on the two occasions described above, behind ring A, was very rapid, but not instantaneous; I should estimate that it occupied about half a second, and that the final brightening when clearing the ring took about the same time. It was certainly nothing like the disappearance and reappearance of a star in the case of an ordinary lunar occultation.

The times given above for the two brightenings in ring A, and for the final reappearance are, I believe, correct to the nearest minute.

The apparent position of the star for 1917 Feb. $9^d\ 10^h$ G.M.T. was:—

$$7^h\ 49^m\ 23{\cdot}163^s, +21^\circ\ 19'\ 15''{\cdot}43.$$

The phenomenon described above was also observed by Mr. J. Knight, of Rye, who has kindly furnished me with some details. He used a 5-inch refractor, power 180.

He states that he never lost sight of the star behind the ball, but that it was projected on the edge thereof; probably, like the projection witnessed by myself on the edge of ring A, an effect of irradiation. He describes the star as seeming to "eat its way" into the ring "in a varying manner," with occasional appearances and disappearances, and as having the exact appearance of a

Occultation of B.D. +21° 1714, by Saturn's Ring, 1917 Feb. 9.

satellite of Jupiter in transit; also as seeming to "float in the ring." He also mentions that when seen through the Cassini division its image appeared elongated. I cannot help thinking that these appearances must be, to a large extent, due to the bad seeing which he unfortunately experienced; certainly, to my eyes, the star never looked in the least like a satellite in transit.

He further states that he saw the star pass along the Cassini division "in an exceptionally distinct manner"; but adds, "when it left that division I could not be sure that I saw it at all until it emerged."

He further concurs with me as to the pale appearance of the star when in the Cassini division, and states that, although very distinct in the division, it was by no means as bright as when clear of the planet.

The attached diagram has been drawn to scale from the data given in the *N.A.* for the rings and ball; the lower of the two parallel straight lines represents the path of the star relative to the planet, from positions of the planet and star kindly furnished to me by Dr. Crommelin, the computed relative positions at 8^h, 10^h, and 12^h being as there shown.

The upper of the two straight lines shows the relative path which best represents my observations, although it would seem that this relative path would involve, if correct, the disappearance of the star behind the ball, which does not seem to have taken place. The polar semidiameter of the ball has been corrected for the tilt of the axis, and the position of the planet for parallax.

It seems fairly clear, from comparison of Mr. Knight's observations with my own, that—

(1) the star was visible through ring A;

(2) that while behind ring A it was seen, though not with anything like its full brilliancy, through Encke's division, and through another exterior to the same;

(3) that it did not actually pass behind the ball, although it must have made a very close approach thereto; and

(4) that, as far as can be judged from the present observation, the measures of the rings, on which the data given in the *N.A.* are based, would appear to be somewhat too small.

I have, up to date, heard of no other observations of this phenomenon.

Blackheath:
1917 *March* 6.

The Surface Currents of Jupiter during the Apparition of 1916–17. By Scriven Bolton. (Plate 3.)

The main factors concerning the observations of 1916–17 may be expressed here—

Jupiter in opposition	1916 October 23.
Period covered by the observations	1916 September 6 to 1917 February 12 inclusive.
Instrument used	26-inch reflector.
Powers employed on same	300, 380, 500.

The scope of the work executed during the above-named period is as under:—

Total number of C.M. transits of markings recorded	4115
Total number of C.M. transits utilised in the final reduction	3896
Number of hours observed	209
Average number of C.M. transit estimates obtained per hour	19·7
Total number of sketches of the surface accumulated	338

With the aid of the aperture above referred to, diligent attention was paid to the high temperate and polar regions. Since the faintest spots were readily visible and could be studied without much effort, and because of the larger image usually obtainable without detriment to definition, the transit estimates of the fainter spots proved in my own case more trustworthy than usual.

The following table has been prepared from a reduction of all the observations selected:—

Table of Mean Rotation Periods of Markings in Different Latitudes.

Chart Reference.	Markings recorded.	Approximate Latitude.	Average Drift in 30 Days.	Number of Selected Objects.	Average Number of Observations.	C.M. Transits utilised.	Date of First Observation.	Date of Last Observation.	Mean Rotation Period.
		°	°				1916.	1917.	h m s
A	Dark spots, N. edge S. Polar Regions.	−50	+ 5·34	5	5·00	25	Oct. 12	Feb. 6	9 55 33·3
B	White spots, S.S. Temperate Zone .	−43	+24·99	19	8·53	162	,, 6	,, 9	9 55 6·4
C	Dark spots, S.S. Temperate Band .	−40	+23·61	22	9·59	211	Sept. 6	,, 6	9 55 8·3
D	White spots, S. Temperate Zone . .	−32	+15·70	23	11·74	270	,, 10	,, 7	9 55 19·1
E	Dark spots and streaks, S Temperate Band	−28	+15·64	19	13·26	252	,, 6	,, 6	9 55 19·2
F	White spots, S. Tropical Zone . .	−21	+10·25	12	10·17	122	,, 10	,, 6	9 55 26·6
	p end, Great S. Tropical Disturbance	−18	+ 9·50	1	18·00	18	,, 13	,, 2	9 55 27·6
	f end, Great S. Tropical Disturbance .	−18	+ 9·75	1	17·00	17	Oct. 3	,, 5	9 55 27·3
F, G	White and dark spots within Great S. Tropical Disturbance	−18 to −21	+ 9·12	14	8·14	114	Sept. 23	,, 4	9 55 28·1
G	Dark crests, S. edge S. Equatorial Belt	−18	+10·50	17	9·47	161	,, 10	,, 6	9 55 26·3
P, S, F, S,	Red spot Bay, *p* and *f* shoulders and middle	−18	+ 3·00	3	17·00	51	,, 15	,, 6	9 55 36·5
H	White spots, central rift, S. Equatorial Belt	−13	+ 4·60	5	5·80	29	,, 28	,, 5	9 55 34·5
I	Dark spots, N. edge S. Equatorial Belt	− 9	+ 6·76	24	11·17	268	,, 6	,, 6	9 50 20·9
J	Dark streaks in Equatorial Band .	± 0	+ 6·77	6	8·00	48	Oct. 9	,, 5	9 50 20·9
K	White spots, S. edge N. Equatorial Belt	+ 8	+ 9·50	15	13·40	201	Sept. 6	,, 9	9 50 17·2
L	Dark crests, S. edge N. Equatorial Belt	+ 9	+ 9·88	21	12·90	271	,, 6	,, 12	9 50 17·7
L	Dark streaks, S. edge N. Equatorial Belt	+ 7	+10·10	4	12·25	49	Oct. 12	,, 12	9 50 16·4
M, N	White and dark spots, N. edge N. Equatorial Belt	+15 to +18	+ 6·54	22	14·55	320	Sept. 6	,, 6	9 55 31·7
			+19·90	8	12·38	99	,, 23	,, 12	9 55 13·4
O	Dark spots, N. Temperate Band .	+23	+ 6·78	28	10·50	294	,, 6	,, 9	9 55 31·4
P	White spots, N. Temperate Zone .	+29	+16·85	27	9·11	246	,, 10	,, 6	9 55 17·6
Q	Dark spots and streaks in N.N. Temperate Band	+36	− 7·03	22	8·14	179	,, 20	,, 6	9 55 50·3
R	White spots, N.N. Temperate Zone .	+45	+15·91	28	8·50	238	,, 28	,, 9	9 55 18·9
S	Dark spots and streaks, edge N. Polar Region	+49	+ 7·90	25	10·04	251	,, 6	,, 6	9 55 29·8
	Totals	..	..	371	..	3896	..	..	..
	Average	..	..	15·5	11·0	162·3	Sept. 26	Feb. 7	..
, J, K, L	All light and dark spots in Equatorial Current	− 9 to +9	+ 8·60	70	11·34	837	Sept. 6	Feb. 12	9 50 18·6
M, N	All light and dark spots along N. edge N. Equatorial Belt	+15 to +18	+13·22	30	13·47	419	,, 6	,, 12	9 55 22·6
	P and *f* ends S. Tropical Disturbance .	−18	+ 9·63	2	17·50	35	,, 13	,, 5	9 55 27·5

Notes on certain deduced Rotation Periods.—In the foregoing table the rotation periods representing the N. Temperate Zone, the S. Polar Band, and the N.N. Temperate Zone differ somewhat from

those usually assigned to the same latitudes. In reducing these observations the results of other observers in the past have not been overlooked.*

The quickened rate of velocity of the Equatorial current proved altogether abnormal, and appeared (to some extent) to be commensurate to the disturbed condition of this part of the globe. The period worked out at 7·7 seconds shorter than that for the last apparition (1915 September–1916 February).†

The white and dark spots and crests along the S. edge of the S. Equatorial Belt, including those within the S. Tropical Disturbance, moved in reasonable agreement with the motion of this disturbance, whereas during the previous apparition they appeared to drift in unison with the Red Spot.

As a result of the progressive diminution in velocity of the S. Tropical Disturbance, and the accelerated motion of the Red Spot, the rotation periods of these two objects differed by only 9 seconds.

The white and dark spots fringing the N. edge of the N. Equatorial Belt (many of which possessed abnormal size and intensity) exhibited two separate rates of motion, the line of demarcation occurring at about $\lambda 204^\circ \pm$. Preceding this longitude the surface rotated in about $9^h\ 55^m\ 31{\cdot}7^s$ (22 spots), while following it to about $\lambda 295^\circ \pm$ an accelerated velocity was evidenced by a period of $9^h\ 55^m\ 13{\cdot}4^s$ (8 spots). Farther to the right the spots exhibited a gradual diminution in speed, until at and beyond $\lambda 312^\circ$ the velocity corresponded with the average value of the zone (excluding the exceptional region). A not dissimilar phenomenon was witnessed in this latitude by Molesworth in 1899.

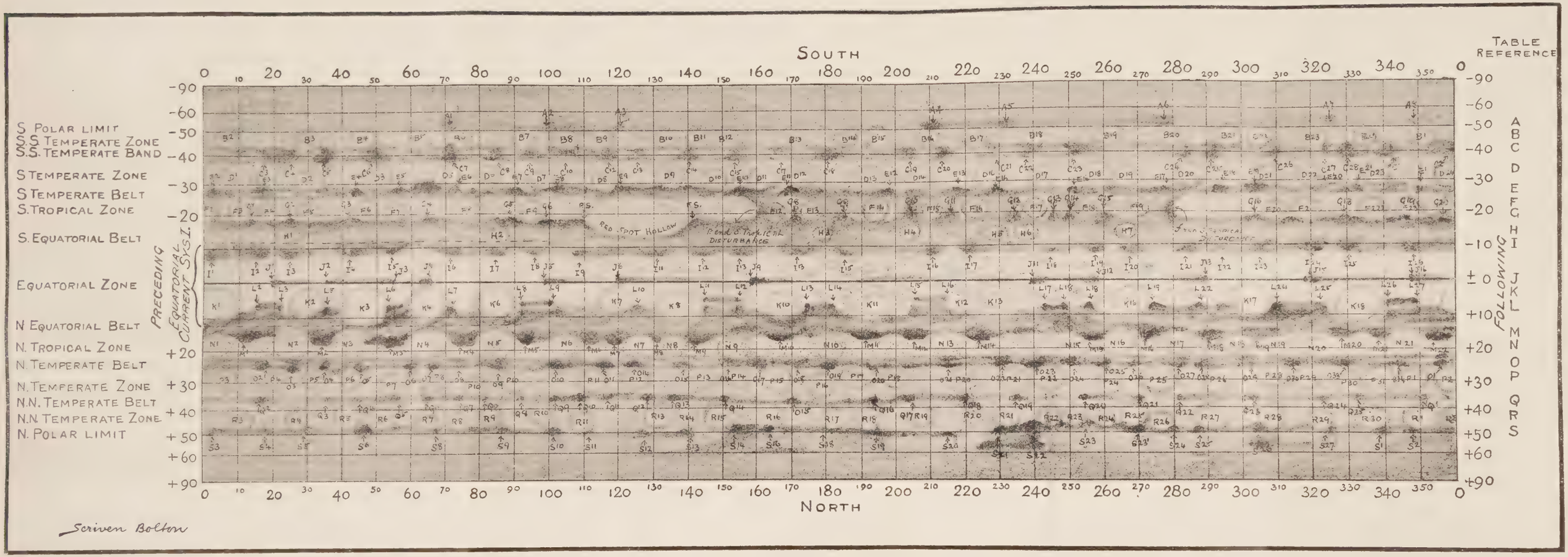
Aspect of the Planet.—The surface features on the whole exhibited somewhat greater activity than for many years past. White, almost phosphorescent, spots abutted on both edges of the intensified N. Equatorial Belt (the darkest stripe across the disc), and formed a series of large bays therein. The N. Temperate Belt was much intensified, and appeared semi-duplex. The S. Equatorial Belt presented unusual activity, as did also the S.S. Temperate Belt, which was widely duplicate. The Red Spot was faintly visible until 1916 December, its disappearance (which was anticipated) being occasioned by the approach of the S. Tropical Disturbance, the preceding end of which caught up to the spot probably about 1917 February 6. During the last fourteen years the spot has practically disappeared during each conjunction with the disturbance named, and the hollow in which it lies has every time grown apparently whiter, a probable contrast effect.

Respecting the colour of the planet, I can fully confirm the late Dr. Percival Lowell and Mon. E. M. Antoniadi with regard to the cherry-red hue of the belts and poles.

* Seeming discrepancies have not infrequently arisen through an alternate manifestation of spots along both edges of a zone or belt participating in two currents.

† *Monthly Notices*, vol. lxxvi., No. 7.

Bramley, Yorkshire:
1917 *Feb.* 22.



Jupiter during the apparition of 1916–17. Key to the markings. Longitudes reduced to date 1916 December 10.

Occultations observed at Eltham in 1915.

By Maurice E. J. Gheury.

The following occultations were observed at Eltham in 1915. Calls made by the war and a protracted illness prevented their reduction from being carried out, and as there seems to be no likelihood of this being done in the near future, the observations alone are given here. The notation and method of the two previous papers (see *Monthly Notices*, vol. lxxiv. p. 540, and vol. lxxv. p. 710) have been followed throughout. The times have been corrected for the latest clock errors, kindly supplied by Mr. T. Lewis.

No.	Date.	G.M.T.	Estimated Probable Error.	Star.	Mag.	Dis. or Reap.	Position.†
	1915.	h m s	s				
54	Feb. 2	11 24 2·6	±0·6	75 Leonis	5·4	R	D
55	2	12 32 19·3	±0·7	76 Leonis	6·0	R	D
56*	21	6 35 27·1	±0·6	B.D. +24° 543	8·7	D	D
57	21	7 4 45·9	±0·7	18 Tauri	5·6	D	D
58*	21	7 14 27·7	±0·8	B.D. +24° 548	8·8	D	D
59*	21	8 20 11·6	±0·7	B.D. +24° 563	8·4	D	D
60*	21	8 54 50·8	±0·7	B.D. +24° 571	7·1	D	D
61*	21	10 46 5·9	±0·7	B.D. +24° 583	8·5	D	D
62	Mar. 25	14 5 2·0	±0·8	μ_2 Cancri	5·4	D	B
63*	Apr. 18	9 54 38·6	±0·8	B.D. +28° 732	8·0	D	B
64*	June 19	10 20 36·1	±0·8	B.D. + 0° 2782	6·4	D	B
65	July 3	13 48 14·8	±0·9	51 Piscium	5·7	R	D
66	Sept. 19	11 5 33·2	±0·8	Rumker 8872	6·6	D	A
67	21	6 59 57·1	±0·8	67 Aquarii	6·3	D	D
68	Oct. 26	11 34 18·3	±0·7	W.Z.C. 341	6·6	R	D
69	29	11 24 10·3	±0·9	B.A.C. 2544	6·3	R	D
70*	Dec. 11	5 41 25·0	±1·0	B.D. −10° 5804	8·5	D	B
71*	11	6 49 27·2	±1·1	B.D. −9° 5896	8·6	D	B

Notes.—Nos. 54, 57, 60, 62, 64, 66, 70: instantaneous.
Nos. 58, 63: difficult.
Nos. 59, 61: haze.
No. 67: haze and bright moon; difficult.
No. 71: just at limit of visibility; the observation may be bad.

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* Particulars of these occultations are not given in the *Nautical Almanac*.

† See *Monthly Notices*, vol. lxxiv. p. 541. The places of observation are close to one another: mean astronomical latitude, 51° 27′ 13″·7 N.; mean geocentric latitude, 51° 15′ 55″·1 N.; mean longitude, $0^h\ 0^m\ 15^s{\cdot}16$ E.; mean altitude, 250 feet above sea-level.

The positions of the stars not given in the *Nautical Almanac* are given below for 1915·0:—

No.	Mean R.A. h m s	Mean N.P.D. ° ′ ″	Catalogue.
56	3 39 15·92	65 23 36·0	*Astr. Gesel.*, 1875.
58	3 40 16·10	65 20 35·6	,,
59	3 41 58·81	65 26 36·1	,,
60	3 43 1·75	65 16 21·7	,,
61	3 46 19·56	65 5 34·5	,,
63	4 56 37·74	61 49 58·5	,,
64	11 18 56·86	89 24 4·3	,,
70	21 54 33·98	100 10 8·9	*Astr. Gesel.*, 1900.
71	21 57 36·71	99 41 30·2	Mean of Cambridge (*u.s.*) 1912, and Vienna, Ottakring, 1904.

Richborough:
1917 *January.*

Differential Star Corrections. By W. E. Cooke, M.A.

This is still one more attempt to shorten the work of the meridian observer, and has special application to zone observations.

Consider a supposititious case, reduced to its simplest elements.

Let P be a known star, and Q an unknown, and let P and Q be observed with the transit circle and all instrumental errors applied. In order to obtain the R.A. (or N.P.D.) of Q on January 1, we may apply the "star-corrections" to the observed values, subtract the P value thus obtained from the known position of P on January 1, and add (or subtract) this difference to the Q value and thus obtain the Q position on January 1.

Suppose the star corrections are $+3^s{\cdot}50$ and $+3^s{\cdot}00$. It will give exactly the same result if we apply these corrections, or if we apply $+0^s{\cdot}50$ and $0^s{\cdot}00$. It is the *difference* between the corrections that matters.

I now propose to obtain values for such differences, rather than to determine the complete "star-corrections."

In order to focus our ideas, let us consider the R.A. side only. Using the old notation (prior to 1916) of the *Nautical Almanac*, the correction is

$$Aa + Bb + C_1c + D_1d + C_2c + D_2d,$$

where $C_1 = t - {\cdot}025 \sin 2L$,

$C_2 = -{\cdot}342 \sin \Omega + {\cdot}004 \sin 2\Omega$,

$D_1 = -0''{\cdot}551 \cos 2L$,

$D_2 = -9''{\cdot}21 \cos \Omega + 0''{\cdot}09 \cos 2\Omega$.

Still further focussing our ideas, let us consider one term only, *e.g.* Aa,

$$\mathrm{A}a = \mathrm{A} \,.\, \tfrac{1}{15} \cos a \sec \delta,$$

and its differential effect upon the two stars P and Q. First let us imagine the two stars P and Q to have the same declination, and to differ by 1^{h} in R.A. The differential correction due to Aa would be

$$\mathrm{K}\,(\text{say}) = \mathrm{A} \,.\, \tfrac{1}{15} \sec \delta d(\cos a),$$

where $d(\cos a)$ means the change in $\cos a$ for the 1^{h} difference in a.

Next let us imagine a third star R of the same R.A. as Q, but differing 1° in N.P.D. The differential correction due to Aa between Q and R would be

$$\mathrm{L}\,(\text{say}) = \mathrm{A} \,.\, \tfrac{1}{15} \cos a d(\sec \delta),$$

where $d(\sec \delta)$ means the difference in $\sec \delta$ for the 1° difference in N.P.D.

The differential correction between P and R would be

$$\mathrm{K} + \mathrm{L} = \mathrm{A} \,.\, \tfrac{1}{15} \sec \delta d(\cos a) + \mathrm{A} \,.\, \tfrac{1}{15} \cos a d(\sec \delta).$$

This is a general expression, as far as the term Aa is concerned, for the differential correction between any two stars differing 1^{h} in R.A. and 1° in δ.

Similarly, for any two stars differing by m^{h} and n°, if $d(\cos a)$ and $d(\sec \delta)$ represent suitable average values for 1^{h} and 1°, the differential correction becomes

$$\mathrm{K} + \mathrm{L} = m \,.\, \mathrm{A} \,.\, \tfrac{1}{15} \sec \delta d(\cos a) + n \,.\, \mathrm{A} \,.\, \tfrac{1}{15} \cos a d(\sec \delta).$$

So far we seem to be only complicating matters, and the final formulæ, if written in full, look rather formidable: but they eventually straighten out and lend themselves to a very simple tabulation.

Applying the above process throughout, we obtain the following scheme:—

$a_1 = \tfrac{1}{15} \sec \delta d(\cos a).$ $\qquad$ $a_1' = +\sin \delta d(\sin a).$

$b_1 = \tfrac{1}{15} \sec \delta d(\sin a).$ $\qquad$ $b_1' = -\sin \delta d(\cos a).$

$c_1 = 1{\cdot}336 \tan \delta d(\sin a).$ $\qquad$ $c_1' = -20{\cdot}045 d(\cos a).$

$d_1 = \tfrac{1}{15} \tan \delta d(\cos a).$ $\qquad$ $d_1' = +d(\sin a).$

$a_2 = \tfrac{1}{15} \cos a d(\sec \delta).$ $\qquad$ $a_2' = -\tan \omega d(\cos \delta) + \sin a d(\sin \delta).$

$b_2 = \tfrac{1}{15} \sin a d(\sec \delta).$

$c_2 = 1{\cdot}336 \sin a d(\tan \delta).$ $\qquad$ $b' = -\cos a d(\sin \delta).$

$d_2 = \tfrac{1}{15} \cos a d(\tan \delta).$

$K_\alpha = Aa_1 + Bb_1 + C_1c_1 + D_1d_1$. $K_\delta = Aa_1' + Bb_1' + C_1c_1' + D_1d_1'$.

$L_\alpha = Aa_2 + Bb_2 + C_1c_2 + D_1d_2$. $L_\delta = Aa_2' + Bb_2'$.

$M_\alpha = C_2c_1 + D_2d_1$. $M_\delta = C_2c_1' + D_2d_1'$.

$N_\alpha = C_2c_2 + D_2d_2$. $N\delta = 0$.

$d(\sin\alpha)$ = change in $\sin\alpha$ for 1^h in α.

$d(\cos\alpha)$ = „ $\cos\alpha$ „

$d(\tan\delta)$ = „ $\tan\delta$ for 1° in N.P.D.

$d(\sec\delta)$ = „ $\sec\delta$ „ „

Further, let $\alpha_0\delta_0$ be some arbitrarily selected position near the middle of the group to be reduced for any given evening, $\alpha\delta$ the R.A. and Dec. for any star.

Then

$$d\alpha = (\alpha_0 - \alpha)(K_\alpha + M_\alpha) + (\delta_0 - \delta)(L_\alpha + N_\alpha).$$

$$d\delta = (\alpha_0 - \alpha)(K_\delta + M_\delta) + (\delta_0 - \delta)L_\delta.$$

The quantities A, B, C_1, D_1, have already been published in the *Monthly Notices of the R.A.S.*, vol. lxvi. p. 544. They have been called A°, B°, C°, D°, and are given for every tenth day, with t as argument.

C_2D_2 are given on p. 545, where they are called x and y: and are tabulated for every 5° of ☊.

The object of the present communication is to recommend the tabulation of

$$K_\alpha L_\alpha M_\alpha N_\alpha \qquad K_\delta L_\delta M_\delta$$

by any astronomer who is making any form of zone observations.

By suitably arranging the work, the tabulation for the zone of, say, 15° is not a very lengthy undertaking, and will be found to lead to a considerable simplification of the daily routine.

The practical arrangement of the tables and method of use can best be understood by an extract from those computed for the Sydney Zones, 50°–65° south declination.

Let us suppose that on 1906 July 22 we were observing stars between 2^h and 4^h in R.A. and 50°–60° south declination.

Denoting by t the interval in days since the beginning of the year, and ☊ being the mean longitude of the Moon's ascending node, we have

$$t = 202, \quad ☊ = 132^\circ.$$

We shall select $3^h : 55^\circ :$ as our standard position, and from the tables extract the necessary quantities for 2^h, 3^h, and 4^h. The following is a portion of the table for 2^h:—

	Kα (per hour).				Lα (per degree).		
t.	50.	55.	60.	65.	50–55.	55–60.	60–65.
180	−·64	−·72	−·84	−1·01	−·037	−·050	−·069
	−5	−6	−6	−8	+7	+9	+13
	−3	−4	−5	−5	+7	+10	+14
200	−·72	−·82	−·95	−1·14	−·023	−·031	−·042
	−2	−2	−3	−3	+7	+10	+15
	0	0	0	−1	+8	+11	+15
220	−·74	−·84	−·98	−1·18	−·008	−·010	−·012
	+2	+2	+2	+2	+7	+10	+14
	+3	+3	+3	+4	+7	+10	+13
240	−·69	−·79	−·93	−1·12	+·006	+·010	+·015

		Mα.				Nα.	
☊.							
°							
120	+16	+19	+23	+28	−·003	−·004	−·005
	0	0	+1	+1	−5	−6	−8
			0	0	−4	−6	−8
140	+16	+19	+24	+29	−·012	−·016	−·021
	0	0	−1	−1	−4	−5	−7
	−1	−1	−1	−1	−4	−5	−7
160	+15	+18	+22	+27	−·020	−·026	−·035

From this and corresponding tables for 3^h and 4^h we obtain the following:—

		55°.	50–55.	55–60.
2^h	Kα Lα	−·82	−·022	−·029
	Mα Nα	+·19	−·009	−·011
	Sum	−·63	−·031	−·040
3^h		−·72	−·043	−·055
		+·20	−·003	−·002
	Sum	−·52	−·046	−·057
4^h		not	−·060	−·079
		required	+·004	+·005
	Sum		−·056	−·074

The sums form the skeleton of the following extended table. It should be noticed that, under the heading 55°, the first sum −·63 represents the relative correction between 2^h and 3^h, and so is the correction to be applied to 2^h to reduce it to our adopted standard 3^h. The correction to 3^h is of course zero. The quantity −·52 is the relative correction between 3^h and 4^h, and so +·52 is to be applied to 4^h to reduce it to 3^h.

Also note that in order to avoid troubling about signs with the argument δ, the signs under the heading 55–60 have been reversed, so that −·040 (to reduce 55° to 60°) becomes +·040 (to reduce 60° to 55°, our adopted standard).

	Arg. R.A. only,	Arg. R.A. and Dec.	
		50–55.	55–60.
h m	s	s	s
2 00	−0·63	−0·031	+0·040
10	− ·52	− ·034	+ ·043
20	− ·41	− ·037	+ ·046
30	− ·30	− ·040	+ ·049
40	− ·20	− ·042	+ ·052
50	− ·10	− ·044	+ ·055
3 00	0·00	− ·046	+ ·057
10	+ ·09	− ·048	+ ·060
20	+ ·18	− ·050	+ ·063
30	+ ·27	− ·052	+ ·066
40	+ ·36	− ·054	+ ·069
50	+ ·44	− ·055	+ ·072
4 00	+ ·52	− ·056	+ ·074

This table is now ready for use. To each star we apply two quantities, one from the second column, with argument R.A., and the other from the third or fourth column, with arguments R.A. and Dec. In the latter case the tabular quantity is for 1° and must be multiplied by the difference between the star's Dec. and 55°. The following may be taken as an example—

R.A. $2^h\ 35^m{\cdot}2$, $\delta\ 52°{\cdot}3$.

The first quantity is $-0^s{\cdot}25$, direct from table.
The second quantity is $-{\cdot}041 \times 2{\cdot}7 = -0^s{\cdot}11$
($2{\cdot}7$ being $55° \sim 52°{\cdot}3$).

The total correction therefore is $-0^s{\cdot}36$.

It is advisable to apply these corrections to all the standard stars, then subtract the observed positions thus corrected from mean positions on January 1. Each star should theoretically give the same difference, and the variations are the accidental errors of observation. The mean of all the differences then becomes a constant quantity to be added to all stars for that evening, and the successive steps may be summarised thus:—

Mean of wires.
Instrumental errors.
Tabular correction, arg. R.A.
,, ,, ,, R.A. and δ.
Constant quantity.
Sum = mean R.A. Jan. 1.

This takes a long time to explain, but only a short time to compute. Even the original tables, though the formulæ look so ponderous,

are very soon formed. It must of course be understood that the standard stars are within the zone covered by the tables.

The declination correction is similar but more simple, because M_δ contains no declination argument, and $N_\delta = 0$.

In conclusion, it may perhaps be pointed out that other corrections can easily be embodied in the above daily table. For example, the instrumental corrections can be combined with L + N as a function of the declination, and the clock rate with K + M.

It is also worth while, if there are many stars in the one evening, to prepare a rough preliminary table for reducing the standard stars, so as to obtain the "constant quantity" for the evening, and then embody this in the more complete table. Thus only two quantities, taken from the table, will reduce each star from "Mean of wires" to "Mean R.A. Jan. 1."

Sydney Observatory:
1916 *December* 6.

Wireless Time Signals: Some Suggested Improvements.

By W. E. and F. B. Cooke.

Anticipating a redetermination of Australian longitudes by means of trans-Pacific radio-signals, some experimental work has been recently undertaken at the Sydney Observatory, with a view of eliminating certain sources of error.

Prior to the war great and rapid progress was made with the new methods, culminating in the determination of the difference of longitude between Paris and Washington by means of radio-signals across the Atlantic. In the course of this work every possible precaution to ensure great accuracy was taken. The results were undoubtedly good, but one gathers from the remarks of M. Baillaud (Director of the Paris Observatory) and others that there are still some outstanding difficulties which will have to be met and overcome.

With those of a purely astronomical character we are not here concerned. The object of this present paper is to indicate a method whereby two clocks or chronometers, separated by some 5000 miles or so, may be compared with an error not exceeding one-hundredth of a second, and with entire elimination of personal equation.

In order that our remarks may be followed, it will be advisable to indicate briefly the general features of the whole operation, and the special difficulties to be attacked.

Three, or perhaps four, stations are concerned. Let us call the two astronomical stations (or those which contain the clocks to be compared) A and B. A third station C (the transmitting or

signalling station) contains some piece of apparatus which radiates a series of "dots" regularly spaced at intervals of *nearly*, but not quite, one second apart. This station should preferably be about midway between A and B, but if this is impracticable, we shall probably have two stations C1 and C2 close to A and B respectively, and each acting alternately as a transmitting station. For definiteness we shall suppose a single station C. For example, if A and B were the Sydney and Lick Observatories, C might be at Honolulu; or with A and B at Sydney and Honolulu, C might be at Nauru (near the equator).

All we expect from C is a series of regularly spaced "dots" at nearly a second interval. The exact times of the "dots" are quite immaterial. It is the object of the observers at A and B to receive this series of arbitrary signals and compare it with the beats of their respective clocks, and this is accomplished by the well-known method of coincidences. Our problem now resolves itself into

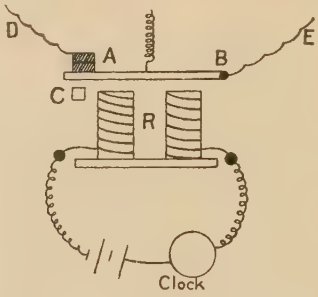

Fig. 1.

this: to determine the exact seconds at which the C signals coincide with the beats of our A (or B) clock. The principal difficulty seems to be this—that a very short sharp "dot" cannot be radiated and received over long distances, and that if the "dot" is of an appreciable length different observers take different parts of it to form their coincidences with their clock-beats. The personal element also arises from the fact that the sound of the radio-signal generally differs greatly from the sound of the clock-beat, however it is introduced. We propose to avoid both these difficulties and eliminate the personal element by means of the following simple mechanical device.

The clock circuit, as usual, passes from the clock contacts through a battery to the relay R, and for all practical purposes R is the clock. The armature of the relay is pivoted at B, and normally rests against the stop at A. When the seconds-impulse comes from the clock the contact A is broken, and the armature rests against the stop C.

Let us now interpose the contact A in the path of the incoming signals. That is, let D A B E be in series with the aerial. *That is all.*

Let us follow the sequence, supposing that the period of the radio-dots is $0^s{\cdot}99$, thus giving a coincidence, with a gain of one second upon the local clock, in every hundred seconds.

With relay open, as shown in the above diagram, the radio-dots come through uninterruptedly, but with relay closed the radio-circuit is broken and we hear nothing. For brevity let us call the clock circuit *c* and the radio-circuit *r*, and note that it is essential that the duration of the periodic closing of *c* shall be greater than the duration of the *r* signal. *E.g.*, if the signal occupies $0^s{\cdot}1$, then the *c* must close every second for $0^s{\cdot}15$ or any period longer than this. There need be practically no limitation to the length of the *r* signal, provided that the *c* impulse is a trifle longer.

There will thus occur occasionally a condition when *r* tries to come through but finds *c* closed, and consequently no path available, and we shall then cease to hear the *r* signals for a time. Taking the above figures, this overlap will be $0^s{\cdot}05$, and with *r* gaining about $0^s{\cdot}01$ per second, the *r* signals will find their path blocked for five consecutive seconds, and we shall have silence for that period. In addition, the few *r* signals immediately preceding this silence will be cut short. They will commence to pass, but

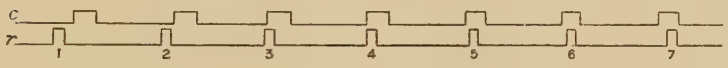

Fig. 2.

almost immediately their path will be blocked by the closing of *c*, and we shall notice a gradual diminution until they finally cease. The coincidence may be taken either as the last audible signal or a second later. Theoretically, it never occurs at any exact second, and we must adopt either the one immediately preceding or following. Practically it makes no difference which we adopt, provided we act systematically; and then even the third place of decimals will, in the long run, be just about correct. To those accustomed to chronographs, the following diagram may help to make the matter clear. The whole sequence is purposely exaggerated.

These two irregular lines show the records as they would appear if one could transfer them to a chronograph.

At 1 and 2 the signals come through without interruption. At 3 the signal starts, but is broken when *c* closes. At 4 the same thing happens, but the making and breaking of *r* is almost simultaneous, and we hear a very short sharp dot. At 5, 6, and 7 *r* cannot get through, and we hear nothing. Real coincidence occurs between 4 and 5, and we may make a rule to take either, provided we adopt the same rule at both A and B. It may perhaps be as well to point out that the shortening of the *r* signals in this way is quite different from the (unsuccessful) attempt to *send* short sharp dots by shortening the duration of key-closing at the transmitter. In our case the signal may normally be of any

duration, and we do not interfere with it until it actually begins to sing. *Then* our clock automatically cuts it out. In practice we have not yet had an opportunity of testing the method over any great distance. We have, however, taken advantage of some signals sent by the Riefler clock at Adelaide (about 700 miles). The determination of coincidence was found to be a very simple matter and quite free from strain. It is far more easy to concentrate the attention upon one series of signal dots and ascertain when they cease than to determine the moment of coincidence of two series, and requires no special training. We occasionally obtained the assistance of friends who had no experience of time observations, and their determinations of the exact moments of coincidence always agreed with our own.

Incidentally a few side issues may be worth glancing at.

(1) It is obvious that *one* transmitting station, where possible midway between A and B, is preferable to two. We may then feel pretty certain that the arbitrary signals reach A and B practically simultaneously.

(2) In Australia the spark and crystal system still holds sway, and we understand that it is also in use in England and France. Through the courtesy of Mr. Ormiston, an American operator, we have been introduced to the arc system, and have been so fortunate as to obtain one of the latest forms of oscillating Audion receivers. In our opinion this combination is greatly superior, for several reasons. In the spark system no current passes until the key is closed, and then some little time must elapse before radiations actually commence. In the arc system the current is flowing through the aerial continuously, and the action of pressing the key simply shorts a few turns of wire in the inductance and thus alters the wave-length. It is quite probable, though we have not yet had the opportunity of testing the question, that very short sharp dots can be sent by this method if required.

Then again the tuning of the arc can be made far sharper than the spark, and the Audion is very much more sensitive than the crystal; *e.g.* with our little aerial at the Observatory we have no difficulty in hearing Tuckerton (New Jersey) at a distance of about 10,000 miles. It would be a simple matter to choose some wave-length sufficiently distinct to be free from interference, and to tune sharply, so that we should hear nothing except the time signals and the atmospherics.

Finally, the receiving observer makes his own "tune." That is, he can control the oscillation of his Audion so as to bring the signals to any musical pitch he desires, and by raising this sufficiently he can cause such a difference between the sound of the dots and the lower growl of the atmospherics as to reduce very considerably the annoyance from the latter.

(3) The main principle can easily be used for the comparison of local clocks or chronometers, in particular for comparing mean and sidereal times. In this case the mean time clock takes the

place of *c*, and the sidereal of *r*; and the latter, instead of being in series with the aerial, is placed in series with a battery and high-pitch buzzer. With this arrangement not only can coincidences be obtained with the greatest ease and certainty, but the slightest want of beat (irregularity of seconds) can be immediately and unmistakably detected.

(4) Alternatively, the radio-signals can be made to *lose*, instead of gain, about one second in 100, and this appears to us to be rather better. In this case coincidence occurs at the *first* perceptible tick after the silence, instead of the last heard. It seemed to us to be easier to describe the gaining arrangement, but our own personal feeling is in favour of the losing ticks.

(5) It is an essential point that the duration of the closing of *c* should be slightly longer than the length of the *r* ticks: and

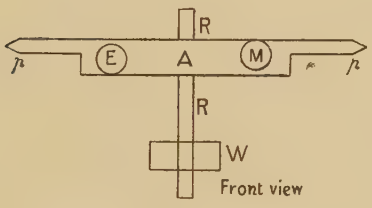

Fig. 3.

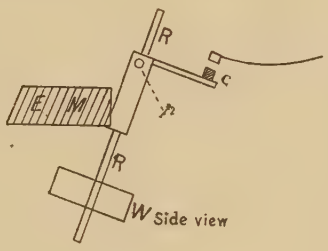

Fig. 4.

to ensure the practicability of always obtaining this adjustment, it is advisable to have some form of slow-acting relay. There are several on the market, but amongst those which we have seen nothing appeared to be quite suitable, so the following form was adopted.

In the above—

EM are the electromagnets.
A the armature, pivoted at *pp*.
R a light rod passing through the armature and carrying a weight W.
c the contact between the armature and a light spring.

Normally the clock circuit is closed, and broken momentarily every second. Therefore, as a rule, the armature rests against the magnets; but when the current is broken it acts as a pendulum, swinging away and forming contact at *c* for a period that is determined by the position of the weight W. This arrangement has been in use for another purpose at the Sydney Observatory for several months, and works very satisfactorily.

Comet Observations made at the Melbourne Observatory, 1914 and 1915.

Micrometer Observations.

Instrument: 8-inch equatorial, square bar micrometer. Observer: J. M. Baldwin.

Comet 1914 *e* (*Campbell-Westland*).

	Melbourne Mean Time.	$\alpha-\alpha_*$.	$\delta-\delta_*$.	Comp.	$\alpha_{app.}$	log $p\Delta$.	$\delta_{app.}$	log $p'\Delta$.	Star Reduction to Apparent Place. $d\alpha$.	$d\delta$.
1914	h m s	m s	′ ″		h m s		° ′ ″		s	″
Sept. 21	8 32 49	−4 37·22	− 6 1·7	8	2 35 27·01	9·9314*n*	−57 5 46·5	0·4825*n*	+3·90	+34·0
,, 22	9 6 36	+0 17·43	+ 2 55·9	10	1 58 10·79	9·8937*n*	−55 35 56·7	0·1133*n*	+4·48	+32·0
,, 23	9 8 6	−8 7·78	+11 7·9	7	1 24 16·18	9·8398*n*	−53 26 47·4	9·7939*n*	+4·72	+30·3
,, 25	8 37 4	+1 47·01	−12 12·5	6	0 28 13·05	9·7485*n*	−47 42 27·4	9·7877*n*	+5·02	+25·1
,, 30	8 28 27	+3 0·49	− 7 53·2	8	23 5 4·11	9·4438*n*	−31 12 17·0	0·1745*n*	+4·60	+18·3
Oct. 3	9 9 18	+4 24·91	+ 3 27·1	10	22 38 53·60	8·9860*n*	−23 1 17·9	0·3559*n*	+4·32	+17·0
,, 6	7 42 40	−3 39·68	− 2 58·0	10	22 22 12·87	9·3221*n*	−16 50 0·7	0·5213*n*	+4·11	+17·4
,, 7	8 36 16	+1 44·91	− 1 21·7	10	22 17 41·51	8·9260*n*	−15 0 17·9	0·5329*n*	+4·03	+16·9
,, 10	8 54 36	+4 7·26	− 2 36·1	2	22 7 23·07	6·2345	−10 32 12·9	0·6026*n*	+3·86	+16·8
,, 12	7 46 27	+1 20·64	− 4 41·3	10	22 2 24·25	9·0500*n*	− 8 11 12·8	0·6386*n*	+3·78	+17·2
,, 15	8 9 30	+0 25·87	− 1 1·7	10	21 55 35·87	7·4430*n*	− 5 11 35·9	0·6737*n*	+3·68	+17·5
,, 18	8 12 47	+4 28·63	+ 3 34·5	10	21 52 29·73	7·9664	− 2 47 51·0	0·7009*n*	+3·55	+17·5
,, 20	8 2 36	+1 50·33	+ 6 17·9	10	21 50 28·99	7·9348	− 1 26 10·3	0·7153*n*	+3·51	+17·9
,, 21	8 1 4	−1 19·89	+ 2 56·2	10	21 49 38·79	8·1813	− 0 50 20·7	0·7214*n*	+3·49	+18·3

Comet 1913 *f* (*Delavan*).

1915	h m s	m s	′ ″		h m s		° ′ ″		s	″
Feb. 12	15 39 26	+1 48·02	− 1 46·8	10	17 36 21	9·6730*n*	−24 27 6	0·5812*n*	+0·40	− 7·7
,, 23	15 8 55	−0 40·21	− 2 32·5	10	17 45 9·12	9·6825*n*	−27 50 58·7	0·5380*n*	+0·73	− 6·7
Mar. 9	15 46 46	+1 40·98	+ 7 36·3	10	17 52 24·79	9·5896*n*	−32 20 9·6	0·2802*n*	+1·23	− 5·1
Apr. 12	11 31 32	−0 4·69	+ 3 52·7	10	17 42 40·91	9·7907*n*	−44 2 39·2	0·3896*n*	+2·80	− 2·2
,, 16	11 48 50	−3 16·44	+ 1 37·0	10	17 38 5·03	9·7728*n*	−45 26 10·1	0·1953*n*	+3·01	− 2·1
,, 20	11 47 31	−2 18·97	+ 5 21·1	10	17 32 38·26	9·7627*n*	−46 47 16·9	0·0172*n*	+3·25	− 2·4

Comet 1915 *a* (*Mellish*).

1915	h m s	m s	′ ″		h m s		° ′ ″		s	″
Apr. 12	13 54 54	+1 52·33	+ 6 7·5	10	18 19 2·47	9·5262*n*	− 3 48 59·8	0·7021*n*	+1·88	−13·4
,, 20	13 16 43	+1 58·98	+ 1 39·7	10	18 29 25·85	9·5567*n*	− 6 9 3·9	0·6869*n*	+2·09	−11·6
,, 30	15 50 37	+2 33·86	− 5 28·4	6	18 43 45·49	8·6701*n*	−10 40 31·8	0·6011*n*	+2·39	− 8·6
May 17	11 29 35	+0 35·12	− 6 11·7	10	19 17 8·43	9·6632*n*	−26 25 43·8	0·5297*n*	+3·07	− 0·2
,, 31	10 30 4	+0 28·88	−11 4·1	4	20 33 1·53	9·9110*n*	−55 36 5·7	0·3642*n*	+4·47	+14·6
June 1	11 2 20	+4 35·16	− 1 59·3	10	20 45 13·59	9·9335*n*	−58 14 22·6	0·1680*n*	+4·68	+16·0
,, 2	10 50 12	+0 14·55	− 1 54·5	10	20 59 2·97	9·9738*n*	−60 46 1·3	0·2570*n*	+4·78	+18·2

Mean Places of Comparison Stars.

Star.	α_{1914} h m s	δ_{1914} ° ′ ″	Authorities.
1	2 40 0·33	−57 0 18·8	Gou. 2916, GZ 2h, 1073, Cp_{80} 1120.
2	1 57 48·88	−55 39 24·6	Gou. 2010, GZ 1h, 1505.
3	1 32 19·24	−53 38 25·6	Gou. 1556, GZ 1h, 807, Cp_{80} 636.
4	0 26 21·02	−47 30 40·0	Cp_{00} 145.
5	23 1 59·02	−31 4 42·1	Gou. 31382, GZ 22h, 1757, Perth 1963.
6	22 34 24·37	−23 5 2·0	Gou. 30863, GZ 22h, 988.
7	22 25 48·44	−16 47 20·1	RC_{90} 6036, AG Wash. 8394.
8	22 15 52·57	−14 59 13·1	AG Wash. 8345.
9	22 3 11·95	−10 29 53·6	AG Camb., M. 7818.
10	22 0 59·83	− 8 6 48·7	$W_{(1)}$ 21h 1334, $SF_{(3)}$ 93, 1110, $Me_{(5)}$ (1914).
11	21 55 6·32	− 5 10 51·7	AG Strass. 7681.
12	21 47 57·55	− 2 51 43·0	AG Strass. 7640.
13	21 48 35·15	− 1 32 46·1	Abbadia (1900).
14	21 50 55·19	− 0 53 35·2	Abbadia (1900).
	α_{1915}	δ_{1915}	
15	17 34 33	−24 25·2	C.P.D. −24° 5927.
16	17 45 48·60	−27 48 19·5	GZ 17h, 2928.
17	17 50 42·58	−32 27 40·8	Gou. 24327, Cp_{80} 9763.
18	17 42 42·80	−44 6 29·7	Cp_{00} 6417.
19	17 41 18·46	−45 27 45·0	Cp_{00} 6410.
20	17 34 53·98	−46 52 35·6	Cp_{00} 6371.
21	18 17 8·26	− 3 54 53·9	AG Strass. 6141.
22	18 27 24·78	− 6 10 32·0	$Val._{1885}$. Vol. 5. Karlsruhe.
23	18 41 9·24	−10 34 54·8	W 18h 949 (1); Münch. 17333 (3); AG Camb. M. 6433 (5).
24	19 16 30·24	−26 19 31·9	Gou. 26496; Cp_{80} 10489; Cp_{00} 2665.
25	20 32 28·18	−55 25 16·2	Gou. 28232 (3); GZ 20h 974 (2).
26	20 40 33·75	−58 12 39·3	Gou. 28428 (3); GZ 20h 1224 (2).
27	20 58 43·64	−60 44 25·0	Me_1 1066 (3); Gou. 28835 (3); GZ 20h 1767 (1).

Comet 1914 *e* (*Campbell-Westland*).

Sept. 21. Concentrated towards centre, distribution of light nearly symmetrical round centre, and gradually falling away. Diameter 12′. Naked-eye magnitude $3\frac{1}{2}$.

Sept. 22. More condensed than on Sept. 21, but nucleus still rather diffuse, surrounded fairly symmetrically by extensive coma, perhaps more pronounced to the north. Diameter of coma about 12′. Magnitude (naked eye) $3\frac{1}{2}$.

Sept. 23. First half of observations somewhat troubled by cloud. Latter half good. Mag. $3\frac{1}{2}$.
Sept. 30. Bright moonlight.
Oct. 3. Comet very difficult in bright moonlight.
Oct. 6. Comet nucleus diffuse, and difficult to observe. Mag. $6\frac{1}{2}$. Definition very bad.
Oct. 7. Comet diffuse and difficult. Definition poor.
Oct. 15. Comet faint and difficult.
Oct. 18. Comet faint and very difficult.
Oct. 20. Comet faint, diffuse, and very difficult.
Oct. 21. Comet very faint, diffuse, and very difficult.
Nov. 6. Very faint and diffuse, no pronounced concentration. Quite impossible to observe.

Comet 1913*f* (*Delavan*).

Feb. 12. Well-defined nucleus, mag. 8.
Feb. 23. Good nucleus, mag. about 8. Extended coma, with trail traceable 40′ in finder, fairly bright for 20′. Width through nucleus at right angles to tail 2′.
Mar. 9. Moonlit field. Well-defined nucleus surrounded by slight coma. Mag. of nucleus 9·5 as seen in telescope.
Apr. 12. Well-defined nucleus, mag. 10. Surrounded by extensive coma elongated to N*p*. Diameter of coma 2′ or 3′.
Apr. 16. Nucleus 10 mag., faint coma.
Apr. 20. Nucleus 10 mag. Coma. At first tail suspected for 20′, but not seen afterwards. Comet observations difficult from faintness of object and further difficulties from two faint stars slightly preceding the comet. Fainter than April 16, when mag. 9 would probably be better.

Comet 1915*a* (*Mellish*).

Apr. 12. Diffuse nucleus surrounded by coma more extended to N*p*. Maximum diameter 5′. Mag. 8.
Apr. 20. Total light 8 mag. Concentrated in middle; no stellar nucleus; extensive coma; diameter 6′; elongated towards preceding.
Apr. 30. Comet faint and diffuse against bright background, moon nearly full. Comet fairly difficult throughout, and sky too bright after sixth set. Foggy.
May 17. Fairly sharp nucleus, $8\frac{1}{2}$ mag., surrounded by extensive coma, with apparently a fainter concentration 30″ preceding main nucleus. Central coma bright, rendering observations somewhat difficult.
May 31. Observations difficult throughout, owing to bright moonlight and haze.

June 1. Good nucleus, mag. 8½; easy to observe, but definition and steadiness poor. Extensive coma. Bright moonlight.

June 2. Faint bright patch in tail. Nucleus 8·5; spot extremely faint.

Photographic Observations.

Instrument: astrograph. Observer: J. M. Baldwin. Measurer: C. Peel.

Comet 1913*f* (*Delavan*).

	Melbourne Mean Time.	Astrographic Positions. α_{1915}	Astrographic Positions. δ_{1915}	Annual Aberration. $d\alpha$.	Annual Aberration. $d\delta$.	Parallax Factors. $\log p\Delta$.	Parallax Factors. $\log p'\Delta$.	Catalogue.
1915	h m s	h m s	° ′ ″	s	″			
May 6	9 10 30	17 2 33·83	−51 30 21·4	+1·85	+ 3·7	9·8569$_n$	0·2815$_n$	Cp. Ast$_{00}$.
,, 17	7 53 48	16 35 36·30	−53 47 15·2	+2·21	+ 0·4	9·8828$_n$	0·2683$_n$	Gou.
June 1	6 47 23	15 56 38·33	−55 17 25·7	+2·32	− 5·1	9·8800$_n$	9·9846$_n$	Gou.
July 1	9 10 49	15 0 38·05	−54 14 13·9	+1·41	−12·5	9·1791	0·3816	Gou.
,, 13	10 57 56	14 50 26·28	−53 17 45·8	+0·92	−13·2	9·7878	9·3277	Gou.

Comet 1915*a* (*Mellish*).

1915	h m s	h m s	° ′ ″	s	″			
July 3	6 30 13	5 42 52·54	−48 5 8·7	−1·98	+ 4·6	9·8084	0·7433$_n$	Cp. Ast$_{00}$.

The astrographic positions are referred to the equator and equinox of 1915·0, and are corrected for the part of the aberration due to the earth's motion.

Melbourne Observatory:
1917 *Jan.* 22.

The following reports of the Sydney and Melbourne Observatories were received too late for insertion in the Annual Report of the Council:—

Sydney Observatory.
(*Director, Mr. W. E. Cooke, Government Astronomer.*)

After four years' strenuous exertions to obtain the removal of the Observatory to a more favourable locality, the Government Astronomer was definitely informed in August that on account of the war the reorganisation must once more be postponed. Under these circumstances the Astronomer has definitely ceased his efforts in that direction, and arrangements are being made for him to reside in the old Observatory quarters and do the best he can under the old conditions.

Considerable attention has been given to the astrograph. It has been structurally modified and completely readjusted, and is now very nearly ready for a fresh start.

The main energies of the staff have been directed to the reduction of the accumulated meridian observations. The assistance of two young ladies has been obtained, and steady progress has been made.

During the year a Board of Visitors was appointed by the Government, and several meetings have been held. Most of the business consisted of a discussion as to what use, if any, was to be made of the Melbourne measures of the Sydney Catalogue plates. Eventually it was decided to refer the matter to the Astronomer Royal, and a letter has just (1917 January) been received from him advising the publication of the measures already made. The Board has not yet had time to consider Sir Frank Dyson's letter, but the reduction work has been temporarily laid aside, and all available computing energy has been transferred to the preparation of the photographic measures for the press. They are fairly well spread over the regions having plate centres at 52°–59°, and comprise 652 regions out of a possible 960.

An attempt is being made to utilise the chart plates. Reproduction as carried out elsewhere is considered impracticable. There is a valuable collection of these plates, having their centres at 53°, 55°, 57°, and 59° declination. They cover nearly completely, but without overlap, the whole zone from 52° to 60°. Their epochs range from 1893 to 1910, and there has been much duplication. Some of the regions have been taken quite a number of times. The earliest received single exposures from 30 minutes up to 2 hours, and were taken on Cadett and Marion plates, and the latest series have triple exposures of 30 minutes and were taken on the standard Ilford plates. The earlier ones seem to have been focussed for the centre of the plate, and the images are therefore bad in the corners. The triple exposure charts are much better. Altogether there is a mass of material too valuable to lose, so two schemes for utilising it have been considered, and one is already in operation. Dealing first with the latter, pairs of plates covering the same region, and having epochs at least ten years apart, are being selected and sent to Mr. Innes, Director of the Union Observatory of South Africa. There they are being examined with the blink microscope, and a catalogue will eventually be formed of all measurable proper motions. From the first preliminary survey it appears probable that the entire zone 52°–60°, with the exception of 115 regions, is available for this treatment; and our first care, as soon as a fresh start is made, will be to retake those missing regions.

The second project is to select the best photograph of each region and reproduce it in some form or other, so as to make a photographic atlas of the entire zone; but that is at present only in the experimental stage.

It will be seen that the main scientific work of the Observatory

at present necessarily consists of the digestion and most practical utilisation of the great mass of accumulated observations, both photographic and meridian, taken during the last quarter of a century. It will be unwise to recommence a new programme of observational work, except such as is required to complete the existing gaps, until the whole of the material has been definitely handled.

The University, practical, and popular activities of the Observatory have been continued as usual.

Melbourne Observatory.
(*Dr. J. M. Baldwin, Acting Government Astronomer.*)

Transit Circle (*8-inch*). — The observations for the year include :—

	Number of Observations.	
	R.A.	Z.D.
Clock stars . . .	421	242
Azimuth stars . . .	136	106
List stars . . .	534	537
Miscellaneous . . .	74	75
Total . .	1165	960

Collimation has been obtained 70 times; level, 130; nadir, 118; and runs 21 times.

The exceptionally cloudy weather of the latter half of the year has interfered very seriously with the amount of observing, on occasions ten to fifteen days elapsing without an observation being possible.

Astrograph.—The following plates have been secured :—

Catalogue	4
Triple chart	18
Oxford areas	1
Pole	15
Adjustment	2
Rejected	2
	42

The work on the mounting for the 6-inch doublet has been continued during the year, and the instrument is now ready for hoisting into position. It will be placed in the dome above the roof of the main building formerly occupied by the $4\frac{1}{2}$-inch tele-

scope, which now serves as guiding telescope for the 6-inch. The width of the shutter opening has been doubled, and for the new shutter the mode of balancing described by Dr. Maw (*M.N.*, lxxiv. 2, 1913) has been adopted, and has proved entirely satisfactory.

8-inch Equatorial.—Observations, as opportunity offered, have been made of the variable 191033, but no other work has been done with this telescope during the year.

The instrument has, as usual, been set apart for visitors on three nights in each lunation.

Reduction of Meridian Observations.—The apparent places of all stars are completed to date, and the reduction from apparent to mean place for 1915 is in progress.

The introduction to the General Catalogue 1890 has just been received, and will be printed as soon as possible.

The manuscript of the General Catalogue 1900 has been prepared to $19^h\ 53^m$ and is being proceeded with.

Reduction of Astrographic Plates.—The reduction of the measured co-ordinates to millimetres, and the application of the réseau corrections, have been completed to $1^h\ 36^m\ -74°$.

The measured co-ordinates and diameters have been copied for the printer to $14^h\ 50^m\ -67°$.

The intercomparison of overlapping plates has been completed to $2^h\ 6^m\ -66°$ with $2^h\ 10^m\ -67°$.

The identification of C.P.D. stars has been extended to $14^h\ 50^m\ -67°$.

Twenty-three pairs of astrographic plates, with a minimum time interval of fifteen years, were forwarded to Mr. Innes at Johannesburg for examination with the blink microscope. The results of the examination will be published by Mr. Innes.

Annular Eclipse of the Sun, 1916 *July* 30.—This was observed at Glen Thompson, a station on the central line of eclipse, by Mr. Merfield. The longitude of his station was determined by telegraphic exchange of time-signals with the Observatory on four nights, the latitude and time being determined with an altazimuth. The first contact was observed through cloud, the first internal contact under favourable conditions, and the second internal contact through cloud. The last contact could not be observed. The reductions of these observations are almost complete.

Magnetic Observations and Reductions.—The absolute value of the earth's magnetic field has been determined fortnightly throughout the year, and the scale value of the Adie recording instruments has also been determined at regular intervals. Owing to the lack of assistance, no curves have been measured during the year, but the classification of the curves has been commenced from 1916 January 1, and the results have been forwarded quarterly to De Bilt.

During the year sanction was obtained for the erection of a new magnetic observatory. The building will be of wood and insulated. The general design is similar to that of the U.S. Coast

and Geodetic Survey magnetic observatories, the total thickness of insulation being 18 inches.

It has been decided to erect the building near Toolangi, about 35 miles N.E. of Melbourne, and over 8 miles from the nearest railway line.

An intercomparison of the Melbourne absolute instruments with those of the Carnegie Institution of Washington, used by Mr. Parkinson, was obtained on May 31.

Seismograph.—Records have been taken as usual, and have been read off regularly since January 1, and the results forwarded to Shide Observatory.

The time service has continued as in 1915, and so have the registration of tides at Williamstown, the rating of chronometers, and other miscellaneous services.

The verification of the secondary standard weights and measures and their adjustment has proceeded at intervals during the year as time allowed, and is not yet completed. With the depleted staff it is found impossible to give continuous attention to this or any other long piece of work.

Personal.—None of the vacancies mentioned in last year's report have been filled, and the staff has been further reduced by the resignation of the last temporary assistant from the astrographic bureau and by the enlistment of Mr. Cornell (astrographic observer), so that now there are only two computers engaged on the astrographic reductions.

Errata in Prof. de Sitter's Papers on "Einstein's Theory of Gravitation."

First Paper:

Vol. lxxvi. p. 714, equation (28), first term should be $r\gamma_2'$.

,, p. 714, footnote, middle formula B, insert ν'' before the + sign.

,, p. 715, equation (33) B, should read—

$$\alpha = \beta = \frac{2\lambda^2}{r} m(r) + 2\lambda^2[\mathrm{N} - n(r)].$$

,, p. 719, line 8 (formula), *for* $-1''{\cdot}75$ *read* $+1''{\cdot}75$.

Second Paper:

Vol. lxxvii. p. 162, formula (82), first line. In denominator of second term, *for* r_ν^2 *read* r_ν^3; and on right-hand side, *for* $4\lambda^2$ *read* $4\lambda^4$.

Erratum in Annual Report.

Vol. lxxvii. p. 394. In list of persons who have contributed to the Library, etc., *insert* E. B. Knobel, Esq.